Physical Activity in School Travel: A Cross-Nested Logit Approach

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Abstract

This paper considers school access by both active (walk, bike), quasi-active (walk to transit) and non-active modes (car) in a two-level cross-nested logit framework. A sample of 3,272 middle and high school students was collected in Tehran. The results of the cross-nested logit model suggest that for people who choose walking, increasing a 1 percent in home-to-school distance reduces the probability of walking by 3.51 percent. While, this reduction is equal to 2.82 and 2.27 percent as per the multinomial and nested logit models, respectively. This is a direct consequence of the model specification that results in underestimating the effect of distance by 1.24 percent. It is also worth mentioning that, a one percent increase in home-to-school distance diminishes the probability of taking public transit by 1.04 among public transit users, while increases the probability of shifting to public transit from walking by 1.39 percent. Further, a one percent increase of the distance to public transport, decreases the probability of students' physical activity, approximately, 0.04 percent.

Keywords: Public Transit; Active Mode of Travel; School Trips; Tehran

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1 Introduction

A mushrooming literature has studied the influential parameters on choosing "green" modes of travel.

Public transport is actually a combined transportation mode, as a walking trip is part of most public transit trips. Hence, taking public transit provides an opportunity to accomplish a portion of the suggested daily physical activity, particularly for children (Bopp et al., 2015; Saelens et al., 2014). Studies (Salmon and Timperio, 2007) recommend at least 60 minutes of daily physical exercise for students. This recommendation might be at least partially realized through various forms of green modes of transportation during school trips (Tudor-Locke et al., 2001). Studies (Sallis et al., 2004) have also shown that utilization of different forms of green modes of transportation increases daily energy expenditures and cardiovascular fitness, and decrease obesity, blood pressure, and heart attacks.

Although there are a few studies (Bekhor and Shiftan, 2010) investigating public transit as a combined mode, the public transit mode has not yet been modeled as a both active and non-active travel mode in a simultaneous framework. Understanding the quantitative share of the public transit mode in active and non-active modes of travel 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 cross-nested logit (CNL) framework. In this vein, a sample of 3,272 middle and high school students was collected in the Megacity of Tehran. This reveals the fact that promoting both walking and public transit is the backbone of a successful program that aims to boost physically active lifestyle among children.

(Besser and Dannenberg, 2005), for example, introduced the use of public transport as a way for protecting health and providing physical activity among 3,312 American residents. By calculating the walking time for access and egress of public transit, the results of the study showed that public transit users spend 19 minutes on average for walking to and from transit stations; while, only 29 percent of these people spend over 30 minutes walking. Studies (MacDonald et al., 2010) also indicate that walking to transit stations has a positive correlation with using walking mode in daily trips.

(Bekhor and Shiftan, 2010) employed a series of logit models namely, multinomial, nested, cross-nested, and kernel 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. This study found that for avoiding the model misspecification issue, the park and ride, a combined transportation mode, should be investigated in a cross-nested logit model. To the best of the author's knowledge, this has been the only study in which the public transit mode is utilized as a combined mode in a cross-nested logit framework.

From the public transit role perspective, despite the extensive focus on promoting active and public transportation modes, very few studies (Besser and Dannenberg, 2005; Bopp et al., 2015; Saelens et al., 2014) have examined public transportation mode as a quasi-active mode of travel. Edwards (Edwards, 2008), assessed the net increase in walking associated with taking public transit by applying a Tobit model on 28,771 sample of 2001 National Household Transport Survey. The results show that taking public transit associates with 8 to 10 additional minutes of walking per day. In 2009, Lachapelle and Frank (Lachapelle and Frank, 2009) employed a multinomial logit 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, moderate physical activity, and often walk greater distances between destinations. Further, MacDonald et al. (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 demonstrate that the use of LRT is associated with an average 1.18 reduction in BMI.

The current literature, however, has certain shortcomings that motivated the authors to address the gaps to a possible extent. First, previous studies employed descriptive analysis to understand the amount of physical activity for public transit. Second, taking public transit should be partially considered as active, since walking almost always is part of the access and egress trips. None of the previous studies, however, considered this mode as a quasi-active mode in their econometrics model structures. Lastly, the public transit and walking mode use have a reciprocal relationship that increasing one might diminish the other.

The rest of paper unfolds as follows. Next, the modeling methodology is explained followed by a description of the empirical data that is collected for this purpose in Tehran. The estimation results of a cross-nested logit model is, then, proposed to determine the explanatory factors in the green mode choice decisions and to quantify the share of public transportation mode in both active and non-active branches. Finally, the paper ends with concluding remarks and suggestions for future studies.

2 Survey Design and Data Collection

This study is based on a cross sectional survey that was conducted in May 2011 among 4,700 middle and high school students in Tehran. A pilot survey was conducted in November 2010, to identify problematic questionnaire designs, unclear questions, and to obtain an initial estimate of the response rate, response bias, and survey cost. Next 500 students from 2 high schools and 2 middle schools were randomly selected in Tehran, from which 341 completed questionnaires were received. Dillman (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 school. The survey included 12 questions on the socioeconomic and transportation information. Many parents ignored open-ended questions on the family income, occupation of the family head, and the reasons behind choice of transportation mode. Therefore, such items were reformed to be included in the close-ended questions with adequate answer categories for the final version based on the recommendations of Lazarsfeld (Lazarsfeld, 1944).

The final form had 19 questions divided into two sections. Socioeconomic and demographic questions, such as number of children, level of education, car ownership, number of driver licenses in the household, occupation, and income, were in the first section. While, the second section on the school trip information covered questions such as travel modes to and from school, parents' priorities in choosing a mode, walking time to school, and transportation cost. 100 cash prizes ranging from 15 to 50 US dollars were offered to randomly selected students who 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 in charge of distributing them among students. Parents were asked to complete the survey and send it back to school. Finally, 76 percent of the total 4,700 envelopes that were distributed in 94 schools were returned. An initial screening resulted in excluding 131 envelopes from two schools, because evidence was found that parents did not fill them out. A minimum response rate of 64 percent was obtained from the remaining 3,441 questionnaires. This rate of response is deemed satisfactory for this type of study (Schutt, 2011).

About 60 percent of the collected forms were from the public schools, which is fairly compatible with the actual share of 59 percent for the public middle and high schools in Tehran. All-girls schools, further, have a share of 59.7 and 50.5 percent, respectively, in the sample and population. Moreover, high schools have a share of 40.5 percent, of which 58 percent are from the all-girls schools. The lowest rate of response was observed for the occupation question, for which 10 percent of the parents refused to answer. Only 43 and 24 individuals refused the questions about household income, and number of cars in the household, respectively.

A preliminary analysis of the data shows that 43 percent of students use walking on their way to school. For the return trips, on the other hand, this number rises to more than 49 percent. Previous studies (Yarlagadda and Srinivasan, 2008) found parents tend to drive their children to school, while driving to work in the mornings. In the afternoons, however, many parents cannot leave their work to pick up the kids. Students could have other reasons for using walking on their return trips. For instance, they have a more flexible schedule in the afternoon, and they, particularly girl students, would usually like to socialize and spend some time with their friends on the way back home. Iranian girl students are more restricted than boys in outdoor activities for several reasons that are rooted in cultural and behavioral characteristics of Iranian families. As a result, girls find the school trips as an opportunity to socialize and hang out with their friends. Almost a third of the parents just drove to school to drop off their kids, while 35 percent of them form a trip chain on their way to work. For return trips, on the other hand, 38 percent of parents drive just to pick up their kids, and 16 percent of them pick the kids up on the way back home. In accordance with our study, Leslie et al. (Leslie et al., 2010) found girls are more likely to walk to school, but were less likely to bike. However, girls are more likely to utilize active modes of transportation in school trips overall. In Tehran, girl students are not permitted to choose bike mode of travel for some religious and ideological reasons. Hence, the share of biking equals zero for girls in school trips. Consequently, the total share of biking is l.3 percent and is excluded from data for further analysis. Public modes of transportation such as bus, subway, or taxi are used by 14.6 and 15.6 percent of students to and from school, respectively. Finally, it is worth mentioning that school bus in Tehran is considered as an expensive mode of travel and is not free like most of the western countries. Both private and public schools register school buses at the request of parents for one educational year. School buses are either a van or a taxi car that provide door-to-door services. A summary of the mode choice behavior of the surveyed students is provided in Table 1. A description of explanatory variables used in the study is

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

Category	Mode	From School		To School	
		Boys	Girls	Boys	Girls
Private	Car	3.1	6.2	7.3	10.2
	Carpool	0.4	1.0	0.4	0.9
	Tele taxi	0.4	0.7	0.6	0.6
Public	School Bus	7.0	15.3	7.2	15.1
	City Bus	7.7	4.3	6.7	4.4
	Subway	0.3	0.2	0.3	0.2
	Taxi	2.6	1.6	2.1	1.1
Active	Bicycle	0.7	0.0	0.6	0.0
	Walk	18.2	30.7	15.5	26.8

also outlined in Table 2.

3 Method and Model

McFadden (McFadden et al., 1978) introduced random utility models. Ever since, scholars have shown a growing interest to develop econometrics methods under the umbrella of the discrete choice models. This model assumes that a rational person chooses an alternative that gives him the highest utility among available choices (McFadden et al., 1978). Logit models, including multinomial, nested, cross-nested, and mixed, given their closed-form formulation, which eases the estimation process, have been admired amongst discrete choice models (Train, 2009). A multinomial logit model, however, is usually criticized for the Independence of Irrelevant Alternatives (IIA) property of unobserved random error terms which triggers constrains in some choice situations (Train, 2009). As per the IIA property, for instance, 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, increase the probability of choosing public transit more than walking or biking. Applying a multinomial logit model in this problem may beget model misspecification and mislead policy assessments. To remedy the IIA assumption to the extent possible, nested and cross-nested logit models were developed which remove the IIA property from alternatives to nests. In this vein, alternatives with correlated error terms are embedded in a nest. A cross-nested logit model, also, allows an alternative is located at more than one nest when shares its correlation with alternatives of various nests. This model was employed for the first time by Small (Small, 1987) to investigate the departure time of travel. Then, Vovsha (Vovsha, 1997) named the model cross-nested logit and utilized it to scrutinize the park and ride mode of travel as both public and private mode.

The probability of choosing alternative i from nest n is derived by multiplying the probability of selecting nest n (P_n) by conditional probability of choosing alternative i ($P_{i|n}$) as per Equation 1. Where, (V_i) is the utility that perceives from travel mode i, μ is 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.

Table 2: Description of Explanatory Variables Used in the Study

Variable	Description	Average	Std. Dev.
GENDER	1:Male / 0:Female	0.39	0.48
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* household income	2.09	1.21
H_INCOME	1: If INCOME more than 2 / 0: Otherwise	0.22	0.41
L_INCOME	1: If INCOME less than 2 / 0: Otherwise	0.33	0.47
NON_AUTO	1: Households with no car / 0: Otherwise	0.20	0.40
AUTO_MOR2	1: Households with more than two car / 0: Otherwise	0.18	0.38
PARTTIME	1: If work of,one of parents is part time,/ 0: Otherwise	0.33	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	2.03	0.97
CHILD_7	Number of school children in household (ages7-18)	1.58	0.67
NON_WRK	1: If non worker parents are in household / 0: Otherwise	0.05	0.21
LOW_EDU	1: Parents have less than a high school diploma / 0: Otherwise	0.33	0.47
SB_N_COST	Out-of-pocket school bus travel cost (10 Rials) divide by INCOME	2074.84	1068.43
WALKTRNT	Distance between home and the nearest bus station (meter)	571.21	449.72
POPDENS	Population density in each zone (person per m2)	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 minutes walk time to school	2.63	1.54
DURATION	1: If parents are primarily concerned about their children travel time / 0: Otherwise	0.23	0.52
SAFETY	1: If parents are primarily concerned about their children travel safety / 0: Otherwise	0.31	0.46
RELIABLE	1: If parents are primarily concerned about their children 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
ACCESS	1: If parents have acceptable access to modes of transportation / 0: Otherwise	0.18	0.39
COMFORT	1: If parents are primarily concerned about their children travel comfort / 0: Otherwise	0.30	0.46
D_GENWSCH	1: Influence of WALKSCH variable for boys / 0: Otherwise	1.07	1.65

$$P_i = P_n \times P_{i|n} = \frac{exp(\frac{1}{\mu_n}\tau_n)}{\sum_{n' \in N} \exp(\frac{1}{\mu_n'}\tau_n')} \times \frac{\alpha_{in}^{\mu_n} exp(\mu_n v_i)}{\sum_{i' \in n} \exp(\mu_n v_i')} \tag{1}$$

$$\tau_n = ln(\sum_{i' \in n} \alpha_{in}^{\mu_n} \exp(\mu_n v_i')) \tag{2}$$

To quantify the role of public transit as both active and non-active modes, a two-level cross-nested logit model is employed in this study. Four modes of travel, including private car, school bus, public transit, and walking were considered for school trips. Figure 3 shows the best tree structure among other possible structures. As shown, the upper level has two limbs that cleave into active and non-active limbs. To capture the effect of public transit on activity level of students, this mode is considered in both active and non-active nests. The IV parameters are determined in the estimation procedure. In a two-level cross-nested logit, the IV parameters should be positive and less than one (Wen and Koppelman, 2001). Estimation results for MNL, NL, and CNL models are outlined in Table 3. The IV parameters of the non-active and active limbs are, respectively, 0.76 and 0.62, and both are statistically positive and less than one, according to a Wald and student's t-test. This implies that the multinomial logit model is unstable in this situation. All the variables are significant at more than 90 percent confidence interval, and have a right interpretation sign. Allocation coefficients of the public transit for the non-active and active nests equal 0.47 and 0.53, respectively. In other words, 53 percent of the public transit utility plays a role in the active nest, while 47 percent of which is allocated in the non-active nest. The following section represents the discussion on efficacy of parameters in mode choice decision.

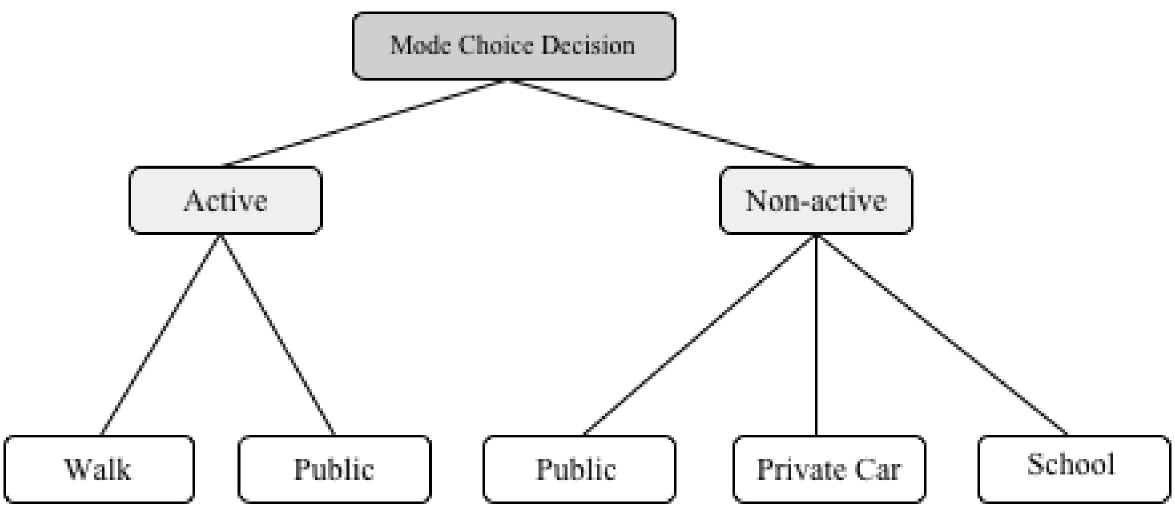

Figure 1: The tree decision for a two-level cross-nested logit model

4 Results and Discussion

This part of the study is dedicated to analyze of influential parameters on travel modes, particularly, walking and public transit in school trips. The variables are divided into three main

Table 3: Summary of multinomial, nested, and cross nested logit models

Variables	Alternatives	Multinomial logit		Nested logit		Cross Nested logit	
		Coefficient	*t-test*	*Coefficient*	*t-test*	*Coefficient*	*t-test*
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	School Bus	-0.75	-6.08	-0.72	-4.63	-0.58	-4.19
Constant		-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
SB_N_COST		-0.0003	-3.63	-0.0003	-2.96	-0.0003	-2.97
Constant	Public	-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
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
D_GENWSCH		-0.39	-3.15	-0.39	-3.06	-0.27	-2.27
Inclusive value parameters:							
Non Active		-	-	0.94	7.15	0.76	5.33
Active		-	-	1	Fixed	0.62	1.92
Allocation Parameters:							
Public Non Active		-	-	-	-	-	0.47
Public 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:				3,272			

categories: 1) household characteristics, 2) urban and transportation system characteristics, and 3) parental concerns.

4.1 Household Characteristics

Among the household characteristics variables, 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 (McDonald, 2008; Nelson et al., 2008), the results indicate that boys are more willing to take public transit or walking than take school bus or private car. It might be due to the parental concerns for the safety of girls in independent trips, which results in a reduction in the utility of using public transport and walking in school trips. The results, also, show that the tendency of older students to use walking and particularly public transit are more than younger students. As expected, families with higher level of income tend to use private car and school bus more. As per previous studies (Martin et al., 2007), educational level of parents has a negative correlation with using public transit and walking modes. In other words, parents with higher education level have are less likely to select public transportation and walking for their children. The relationship between income and household level of education might be a reason behind this preference. Educated parents are more able to either afford the cost of school bus or use private car.

4.2 Transport System and Urban Characteristics

Distance from home to school, distance to public transport stations, population density, and student's school locating in limited traffic zone represent the variables related to transport systems and urban structure that has been found effective in the final model. As expected, an increase in the home-to-school distance begets a reduction in walking. One of the influential variables in use of public transportation is access to transit stations that has received little attention in previous studies. The CNL model results show that by increasing distance to transit stations, the probability of choosing public transit mode reduces dramatically in school trips. Hence, long-term urban policies, namely school siting and public transit station location affect mode choice.

Previous studies (McDonald, 2008; Mitra et al., 2010) suggest that with increasing population density, use of independent modes such as walking and public transit increases in school trips, which is rooted in two main reasons. First, the increased population density means increased residential units in the area and increased eyes on the street that reduces parental concerns for safety of their children. Second, high population density is a feature of areas with small residential units and such a structure, in Tehran, and generally indicates low-income residents. Hence, it is expected that in densely populated areas, people tend to use low cost modes, namely walking and public transit.

Restricted Traffic Zones have a negative correlation with private car use. In Tehran, like many other congested cities around the world, policies are imposed to control and reduce the number of private cars in particular regions of the city. Policies such as increasing parking cost, increasing fuel cost, odd / even rationing (used in Tehran), and cordon pricing cause reduce private car use. Further, these regions in Tehran have such an urban structure that low income households usually live there. As a result, the use of private cars will decrease sharply in these areas and consequently the use of walking and public transport will increase.

4.3 Parental Concerns

Recent studies (Johansson et al., 2006) have shown that the attitude of people towards various modes of transportation plays a pivotal role in mode choice decisions. The influence of parental attitudes toward safety, comfort, travel reliability, and travel duration of various modes of transportation has been considered in the current study. Results designate that parents who are concerned about the safety of their children, are less willing to permit their children to use using public transport and walking to school. Therefore, implementing policies, including "safe route to school" and "walking school bus" programs that have fruitful results, might be effective to promote active and public modes of travel in Tehran.

As expected, the results indicate that parents prefer to use school bus and private car, by considering comfort for their children. Also, those parents who worry about the reliability of the mode of transport prefer to use school bus. Considering this, it could be said that the lack of regular schedule for public transport in Tehran, in contrast to many developed countries, discourages use for both work and school trips.

5 Sensitivity Analysis

Table 4 shows the elasticity of continues variables results for the MNL, NL, and CNL models.

The results of the CNL model suggest that for people who choose walking, increasing 1 percent in home-to-school distance, the probability of walking reduces by 3.51 percent. While, this reduction is equal to 2.82 and 2.27 percent as per the MNL and NL models, respectively. This is a direct consequence of the model specification that results in underestimating the effect of distance by 1.24 percent. It is also worth mentioning that, a one percent increase in the home-to-school distance diminishes the probability of taking public transit by 1.04 among public transit users, while increases the probability of shifting to public transit from walking by 1.39 percent. The elasticity results of the CNL model indicate that by 1 percent increase in level of household income of school bus and private car users, the probability of choosing public transit diminishes 0.23 and 0.14 percent, respectively. Further, a one percent increase in the residential population density escalates the probability of walking by 0.17 percent, followed by 0.17 percent reduction in using public transit.

Access to transit station is another pivotal variable that has a positive correlation with public transit use, and consequently escalating the level of physical activity among children. Although the access to transit has 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 that the probability of taking public transit reduces by 0.29 percent when access to transit diminishes by one percent. As a result, the probability of private car and school bus increases equally by 0.04 percent. While, the nested logit model overestimates this growth twice as much as the cross-nested logit model. Considering public transit as a quasi-active mode of travel allows more flexible structure on the distribution of the unobserved term of public transit utility that results in more realistic behavior. It should be kept in mind that some common reasons behind taking public transit or walking also beget public transit users shift to walking to the extent possible when they face an increase in access to transit.

Among the travel mode specific characteristics, the cost of private car and school bus are found significant in the final model. Studies emphasize that taste variation of people affects their decision-making behavior. 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 responds for all of them may lead to inappropriate policies. To accommodate the alternative taste variation, the cost of private car and school bus use is normalized by the household level of income. As expected, a one percent increase in the cost of private car travel reduces the probability of choosing private car by 0.40 percent and thereby begets people shift to take public transit and walking by a probability of 0.11 and 0.08 percent, respectively. However, this reduction varies considerably, depending on level of income. While the rate of reduction is 0.40 percent among low-income families, the probability of selecting private car diminishes by only 0.20 percent amongst high-income families.

One of the main aims of this study is to indicate how much considering public transport mode as a quasi-active mode, affects on describing active modes of travel. Table 5 illustrates the elasticity of choosing active and non-active nests in nested logit and cross-nested logit models for policy sensitive variables. The results show that, a one percent increase in home-to-school distance decreases the probability of choosing active nest, without considering public transportation as a quasi-active mode, by 2.2 percent. Although by increasing distance, choice probability for walking reduces greatly, but in fact, students' physical activity does not decrease such greatly. The results of the CNL model as a more stable structure, demonstrate this reduction about 0.91 percent. The reason is shifting a significant proportion of walkers to take public transit by increasing the home-to-school distance. The mode-choice model results repetitively demonstrate that travel time and cost of travel are the most important parameters in travel mode choice decision. It is also indeed true that by increasing the distance of travel, the probability of choosing walking is diminished dramatically.

Similarly, a one percent increase of the distance to public transport decreases the probability of students' physical activity, approximately, 0.04 percent. While, the cross-nested logit model due to considering public transport mode as a quasi-active mode, expresses that the probability of being active for students, increases about 0.02 percent. This difference is a direct consequence of model specification, which can easily cause to be presented wrong policies by those who are seeking to promote walking mode of travel while ignoring the active side of the public transit. As expected, the elasticity results of AUT_N_COST and SB_N_COST variables show that one percent increase in the ratio of private car and school bus cost on household' income, increases the probability of being active for students, 0.045 and 0.122 percent, respectively. Such results not only give more awareness to politicians in order to reduce the use of private car, but they also are very effective to improve physical activity and public health.

Table 4: Elasticities for multinomial logit (MNL), nested logit (NL), and cross nested logit (CNL) model structure

Attribute	**Alternative**	**Automobile** *MNL*	*NL*	*CNL*	**School Bus** *MNL*	*NL*	*CNL*	**Public** *MNL*	*NL*	*CNL*	**Active** *MNL*	*NL*	*CNL*
WALKSCH	*Automobile*	-0.71	-0.57	-0.66	0.20	0.30	0.23	0.20	0.30	0.19	0.20	0.15	0.15
	Public	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*	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 Bus*	0.38	0.50	0.43	-1.24	-1.03	-1.20	0.38	0.50	0.36	0.38	0.32	0.29
	Public	-0.24	-0.50	-0.28	-0.24	-0.50	-0.28	1.70	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	-0.70	0.63	0.45	0.89
INCOME	*Automobile*	0.35	0.28	0.45	-0.10	-0.18	-0.17	-0.10	0.18	-0.14	-0.10	-0.07	-0.10
	School Bus	-0.20	-0.26	-0.28	0.45	0.39	0.55	-0.20	-0.26	-0.23	-0.20	-0.19	-0.20
EDU	*Public*	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*	-0.14	-0.19	-0.13	-0.14	-0.19	-0.13	-0.14	-0.19	-0.17	0.15	0.10	0.17
	Walk	-0.14	-0.19	-0.13	-0.14	-0.19	-0.13	-0.14	-0.19	-0.17	0.15	0.10	0.17
AUT_N_COST	*Automobile*	-0.40	-0.29	-0.40	0.09	0.17	0.13	0.09	0.17	0.11	0.09	0.06	0.08
SB_N_COST	*School Bus*	0.17	0.21	0.20	-0.59	-0.49	-0.59	0.17	0.21	0.16	0.17	0.14	0.13

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

Attributes	**Nested Logit** *Active*	*Non-active*	**Cross Nested Logit** *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
SB_N_COST	0.139	-0.048	0.122	-0.059
AGE	0.654	-0.282	0.774	-0.484

6 Conclusion

This study quantified the active travel part of the public transit mode for journeys to school by applying a two-level cross-nested logit model on 3,272 middle and high school students in Tehran. Much of the previous research has been limited to descriptive analysis for quantifying the active share of the public transit by the complexity associated with advanced econometrics models. This paper overcomes the challenges by applying a two-level cross-nested logit 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 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 to avoid any model misspecification issue. Developing such a model structure constitutes an important step forward in understanding the active side of mode choice decision. The model explicitly incorporates a number of influential parameters that affect active modes of travel physically active lifestyle. These include: household characteristics, transport system and urban characteristics, and parental reservations.

To be able to measure the amount of physical activity in transportation network accurately, it is essential to develop a framework that allows looking at both active and non-active sides of travel modes. The findings of the model suggest that 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 the results of this research offer some insights into the role of public transit in active travel by introducing a two-level cross-nested logit model, there are limitations to the study that could be addressed in further studies.

- Studies have explored the effect of built environment variables, including walkability of the neighborhood, density of green space, school, sidewalk, and other land-use variables on mode choice decisions. The results emphasize a significant influence of built environment variables on probability of active modes of travel. Given unavailability of disaggregate built environment data, these information were not utilized in this study.

- Previous studies show that elementary school students have a different travel behavior for the sake of dependency on their parents. For instance, using private car is more prevalent among children younger than 12 years old in school trips. In this study, we only have considered students older than 12 years age. Hence, understanding the travel behavior of this age group of children might be studied in further research.

- The way that children are accompanied to school could be modeled jointly with the travel mode choice decisions in a three-level cross nested logit model, since they are interdependent decisions.

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