

Students' Choice of Active Modes: A Three Level Nested Logit Model

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ABSTRACT

Urban and transportation planners have put a special focus on student health and fitness in the past decade, however they struggle to find effective policies to promote walking and biking for school trips. Commuting to school is an opportunity to embed a regular physical activity in students' daily routines and prevent many health issues that are stimulated by a lack of physical activity during childhood. A three level nested logit model is introduced to explain the motives behind school trip modal selection. Four choice situations, namely walking, driving, school busing, and taking public transit are considered. We, particularly, underscored the significance of model misspecification in terms of policy outcomes, since multinomial logit models are typically adopted in the literature and have strong and, in many cases, unrealistic assumptions. For instance, elasticity analysis of the MNL model showed an indirect elasticity of vehicle ownership of -0.13 for non-automobile modes in the MNL model, while NL model provides different elasticities of -0.12, -0.20 and -0.08, respectively for public, school bus, and walk modes. This misspecification results in over estimating the reduction in the share of students who walk to school when vehicle ownership increases. Moreover, a wide range of policy-sensitive variables along with their effect magnitude was discussed and compared with the previous studies. Particularly, we found that one percent increase in the probability of walking to school is expected for every 0.046 percent increase in auto travel time, 0.075 percent increase in the normalized-to-income cost of driving, 0.088 percent decrease in vehicle ownership, 0.033 percent increase in distance to public transit, or 2.372 percent decrease in commute distance. Safety was also found to be very influential on active commuting, such that addressing the safety concern of parents is expected to increase propensity of active commuting to school by around 60 percent.

Keywords: school trip, mode choice, policy, three level nested logit, Tehran.

INTRODUCTION

A global increase in the children obesity rate has triggered policy-makers to promote a more active lifestyle among students. Many studies have shown that cardiovascular diseases along with several other health issues in adulthood are rooted in a lack of physical activity during childhood and adolescence (Andersen et al., 2003; Andersen et al., 2006). Since walking is the most common form of physical activity for all ages (Saelens et al., 2003), transportation and urban planners struggle to find policies that promote active modes of transportation (AMT). This is, particularly, deemed as an opportunity for children to perform regular physical activity and diminish several diseases throughout their life (Cavill et al., 2008; Tudor-Locke et al., 2002). AMT is also a prospect for city officials to decrease congestion levels in the morning peak hours and thereby mitigate externalities of the transportation system (Rabl and Nazelle, 2012; Pedestrian and Bicycle Information Center, 2008). Parents, on the other hand, have understandable reservations that have led to a significant decline in the share of active modes.

It is essential to study the motives behind the mode choice decisions in school trips, and implement effective policies to promote AMT. Students' mode choice have received growing attention since 1994, when Towner conducted a descriptive analysis on students' modal selection behaviors in England and measured exposure to injury risk in school trips (Towner et al., 1994). Since then a wide range of factors are found to influence students' active travel to school that includes household demographic and socio-economic factors, students' characteristics, built-environment variables, and socio-economics of the residential neighborhood. Table 1 provides a summary of explanatory variables, alternative modes of school travel, and data analysis methods that are applied in some previous studies. According to this table, very few studies (Larsen et al., 2009; McDonald and Aalborg, 2009; Yarlagadda and Srinivasan, 2008) had a complete coverage on the alternative modes, while the rest focused on a subset of alternatives. Moreover, an overview of the explanatory variables reveals that commute distance to school, students' gender, age, and vehicle ownership have been widely used, while other important parameters such as travel time, cost, comfort, and specifications of the transit system have received a limited attention. There are comprehensive reviews (Panter et al., 2008; Karina et al., 2009; Ding et al., 2011; Wong et al., 2011) of the past studies that compared influential factors of active school travel. Furthermore, a review of the analysis method shows that descriptive analysis and binary logit models are predominantly used to explain school travel modes, while very few studies have implemented multinomial logit (MNL) models to explain this behavior. We found very occasional attempts (Ewing et al., 2004) that tried to develop more advanced econometric models (e.g. a nested logit specification), but the outputs was unsuccessful in practice.

The current literature has certain gaps that have motivated this research. First, many previous studies (Mitra et al., 2010; McMillan, 2007) distinguishes between only two alternatives with binary choice models. Although this approach simplifies the modeling methodology, the results provide a vivid picture of school travel modal splits that limits applicability of the findings for policy assessment. Second, a few studies (Ewing et al., 2004; McDonald, 2008a) distinguish between multiple modes of travel for school trips and are based upon a richer dataset, but have potential model misspecification issues. This is because IIA (independence of irrelevant alternatives) property of MNL is not intuitively acceptable in school mode choice decisions, unless a very wide range of explanatory variables reduces the effect of correlated unobserved factors. IIA property implies that characteristics of a third alternative (say school busing) do not change the relative odds between the two alternatives (say walking and driving). This is an inappropriate assumption, since IIA of the MNL model indicates that likelihood of taking a school bus and having the kid walk alone would increase proportionally, if the parents cannot drive their kids to school. This is, intuitively, not true, as parents who take a school bus and those who ride their kids to school could have similar safety reservations and therefore, taking a school bus seems more probable when they cannot drive them to school. Lastly, parents have reservations about their kids' travel method, including safety, comfort, and reliability, that are expected to influence students' mode choice decisions. These variables have received very limited attention in previous models that leads to a form of missing variable model misspecification.

The rest of the paper is structured as follows. First, the modeling methodology is briefly reviewed, followed by a description of the empirical data that is collected for this purpose. The

estimation results of a three level nested logit (NL) model is, then, presented and analyzed from a policy perspective. Finally, the paper concludes with a summary and recommendations for future research.

METHOD

A multinomial logit model has a closed form formula and a straightforward estimation method. However, assumption of IID (independently and identically distributed) extreme value error terms induces certain limitations that are discussed in details by Train (2009). IIA property of MNL is the primary consequence, which is intuitively unacceptable in many cases; unless all the unobserved factors that make the error terms dependent explicitly enter the model (Train, 2009). The NL model specification, an extension of MNL, was introduced by Ben-Akiva (1985) to capture correlation among alternatives to some extents. Although IIA is maintained within each nest, it is relaxed to IIN (independence of irrelevant nests) for alternatives in different nests. This allows variance of errors to differ across the nests, and yet the choice probabilities have a closed-form formula.

The utility that student j perceives from travel mode i is the sum of a systematic utility (V_{ij}) and an error term. The probability of choosing each mode is given by Eq. 1 (Coldren and Koppelman, 2005), assuming a linear-in-parameter function of explanatory variables for the systematic utility and maximizing the likelihood of occurrence for the sampled observations. In this equation, subscript n is omitted for ease of representation, P_m is the probability of choosing an upper-level nest (limb), $P_{n|m}$ is the conditional probability of choosing a lower-level nest (branch) given a limb, and $P_{i|n}$ is the conditional probability of choosing an alternative given a branch. μ is the inverse logsum parameter, also known as the coefficient of inclusive value (IV). τ_n and τ_m are, respectively, given by $\tau_n = \ln(\sum_{i' \in N_j} \exp(\mu_n V_{i'}))$ and $\tau_m = \ln(\sum_{n' \in N_m} \exp(\frac{\mu_m}{\mu_n} \tau_{n'}))$.

$$P_i = P_m \times P_{n|m} \times P_{i|n} = \frac{\exp(\frac{1}{\mu_m} \tau_m)}{\sum_{m' \in M} \exp(\frac{1}{\mu_{m'}} \tau_{m'})} \times \frac{\exp(\frac{\mu_m}{\mu_n} \tau_n)}{\sum_{n' \in N} \exp(\frac{\mu_m}{\mu_{n'}} \tau_{n'})} \times \frac{\exp(\mu_n V_i)}{\sum_{i' \in n} \exp(\mu_n V_{i'})} \quad (1)$$

NL models may be estimated either sequentially or simultaneously. The first estimation method is termed limited information maximum likelihood (LIML), and the latter is known as full information maximum likelihood (FIML) estimation. Although FIML estimation is more challenging and one may encounter convergence problems, Hensher (1986) showed that LIML provides statistically inefficient estimates for a NL model. Therefore, a FIML estimation method is adopted to obtain consistent, asymptotically normal, and efficient estimates.

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Table 1 - Summary of school trips studies

First Author	Year	Country	Age	Mode				AMT (%)	Indicated Parameters								Analysis Method	
				Active (walk / bike)	Automobile	Public Transit	School Bus		Gender	Age	Income	Vehicle ownership	Safety	Comfort	Distance	Travel time/cost		Public Transit
D'Haese	2011	Belgium	11-12	x	x			59	x			x	x		x			Two level Bivariate Regression
Johansson	2011	Sweden	11-15	x	x	x		63	x	x		x						Descriptive
Alemu	2011	Japan	15-18	x	x	x		29		x		x			x	x	x	Multinomial Logit
Leslie	2010	Australia	10-14	x	x	x		56	x									Binary Logistic Regression
Wilson	2010	U.S.	7-12	x	x	x		24		x	x				x			Multinomial Logit
Dyck	2010	Belgian	17-18	x	x	x		58	x				x					Logistic Multi Level
Mitra	2010	Canada	11-13	x	x			70	x	x	x	x			x			Binomial Logit
Larsen	2009	Canada	11-13	x	x	x	x	62	x		x				x			Logistic Regression
McDonald	2009	U.S.	10-14	x	x	x	x	30	x	x	x		x	x	x			Descriptive
Rodri'guez	2009	U.S.	9-11	x	x		x	12		x		x	x		x			Logistic Regression
Nelson	2008	Ireland	15-17	x	x	x		37	x						x			Logistic Regression
Yarlagada	2008	U.S.	<18	x	x	x	x	15	x	x		x			x			Multinomial Logit
Wen	2008	Australia	9-11	x	x	x		32	x	x		x	x	x	x			Logistic Regression
McDonald	2008a	U.S.	7-14	x	x	x		12	x	x	x	x			x	x		Multinomial Logit
McMillan	2007	U.S.	9-11	x	x			22			x	x	x	x	x			Binomial Logit

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Table1- Summary of school trips studies (continued)

First Author	Year	Country	Age	Mode				AMT (%)	Indicated Parameters								Analysis Method		
				Active (walk / bike)	Automobile	Public Transit	School Bus		Gender	Age	Income	Vehicle ownership	Safety	Comfort	Distance	Travel time/cost		Public Transit	
Martin	2007	U.S.	9-15	x				48	x	x	x					x			Logistic Regression
Mota	2007	Portugal	12-16	x	x	x		52								x		x	Logistic Regression
Kerr	2007	U.S.	5-18	x				14	x		x	x							Logistic Regression
Kerr	2006	U.S.	5-18	x				25				x	x						Logistic Regression
Merom	2006	Australia	5-12	x	x	x		30	x	x		x	x			x			Logistic Regression
Timperio	2006	Australia	5-6 / 10-12	x				33		x			x			x		x	Logistic regression
Schlossberg	2006	U.S.	12-15	x	x	x		25					x			x			Logistic regression
de Bruijn	2005	The Netherlands	12-18	x				79	x	x									Three Step Linear Regression
Schlossberg	2005	U.S.	12-14	x	x	x		26					x	x	x				Descriptive
Ewing	2004	U.S.	7-18	x	x		x	8				x				x	x		Multinomial Logit
Evenson	2003	U.S.	12-15	x				10	x	x									Logistic Regression

DATA

To study school trip mode choice decisions, three folds of data were obtained: students' travel information, household demographics, and transportation and built-Environment characteristics. The data was obtained for Tehran, with an area of 700 km², a population of 7.5 million, and 620 traffic analysis zones. Around 15 million daily trips are made in Tehran, 27 percent of which are educational (Municipality of Tehran, 2006). There were 5,352 schools and 1,119,571 registered k-12 students in Tehran in 2010 (Statistics of Minister of Education, 2012).

A paper-based survey was conducted in May 2011, targeting 4,900 middle-school and high-school students throughout Tehran. Primary school students were not covered, as the literature (Panter et al., 2008; McMillan, 2005) suggests a relatively different mode choice decision making process for them. A stratified random sample was taken based on gender and level of education, since schools are gender-segregated in Iran. Further, parents were asked to fill out the questionnaires, because they have more precise information about household demographics and also influence students' decision on mode of travel to school (McMillan, 2005). The survey had a response rate of 72%, and collected information on five folds: household socio demographics (e.g. household size, income, education, vehicle ownership, working status of parents), student characteristics (e.g. age, gender, grade), built-environment attributes (e.g. walk time to school, access to public transit, commuting to or from a restricted traffic zone), school trip behaviors (e.g. escort pattern, primary mode of travel, travel cost, and trip chain), and parental reservations about school trips (e.g. safety, reliability, duration, and comfort).

Four modes of travel are considered in this study: walk, auto drive, school bus, and public transportation. Travel time and cost of each mode is essential for a mode choice study and was obtained from the company of Tehran Comprehensive Transportation and Traffic Studies (2012). Bike mode was not considered, since less than 1 percent of students reported to use bicycles for school trips. Share of each mode, classified by gender, school level, and commute distance is illustrated in Figure 1. This figure also illustrates the relationship between parental concerns and share of active modes among genders.

MODEL

A three level NL model was developed in this study to explain choice of school travel mode among walk, automobile, school bus, and public transportation. Explanatory variables that are used to model the choice situation are defined in Table 2 and estimation results for MNL and NL models are reported in Table 3. The tree of the NL model is structured in a way that the upper level has two limbs that cleave into *active* and *non-active* limbs and the lower level of the *non-active* limb divides into *public* and *private* branches (Figure 2). The *active* limb and *public* branch have one alternative in their lower levels, and thus, the IV parameters are fixed to one. The remaining IV parameters, however, are determined in the estimation procedure. IV parameters have to meet certain conditions in order for a nested logit model to be consistent with the global utility maximization theory. In a two level NL, the IV parameters should be positive and less than one, while in a three level NL, the IV parameter of a lower nest has to be

less than that of the upper nest, as well. The IV parameters of the *non-active* limb and the *private* branch are, respectively, 0.79 and 0.74, and both are statistically positive and less than one, according to a Wald test. This implies that the MNL logit has misspecification issue and, therefore, NL estimates should be employed for policy assessment.

Student's t-test is conducted to show a statistically significant effect of each explanatory variable in Table 3. All the variables are of the right sign and significant at a 99 percent confidence interval in both MNL and NL models, except for school bus travel time (*SBUS_TIME*), income (*INCOME*), and population density (*POPDENS*). Although the latter two variables are significant at 99 percent confidence interval in the NL model, they have a 95 percent confidence interval in the MNL model. Likelihood ratio test is also conducted to measure the overall goodness of fit of the models. The NL model has a McFadden pseudo-rho-squared (likelihood ratio index) of 38 percent which is slightly higher than 32 percent likelihood ratio index of the MNL model. The NL model has a better explanatory power and the significant IV parameters convey a misspecification bias in the MNL model. This would results in incorrect interpretations of the results and eventually leads to misdirecting policy assessments. Significance of model specification is further elaborated in the next section along with an in-depth analysis of the models.

ANALYSIS OF RESULTS

General Discussion

Influential factors on school trip mode choice decisions are reported in Table 3. Further, elasticities of some explanatory variables are estimated through sample enumeration (Table 4). An elasticity value shows the percentage of change in the choice probability as a result of one percent increase in the explanatory variable. Estimated elasticities are compared with the findings of McDonald (2008a) and Ewing et al. (2004) in Table 5. One needs to consider differences in demographics, socio-economics, culture, built-environment, and analysis method, when comparing the outputs. Influence of age and gender of the students are discussed, followed by some household demographics such as income, education, and vehicle ownership on the children tendency to walk to school. Then, parental concerns are discussed that include safety, comfort, reliability, and duration of their kid's travel to school.

We found a positive relationship between students' age and their tendency to walk or take transit to school. On the contrary, the use of school bus decreased with an increase in age. This could be attributed to the fact that when children get older they seek a more independent lifestyle (Fyhri and Randi, 2009). In fact, high-school students are 11 percent more likely to walk compared to middle-schoolers. Contrary findings about the effect of student's gender on AMT utilization are reported in the literature. Although some studies (McMillan et al., 2006) found a higher propensity for boys to use AMT, others (Panter et al., 2010) found the opposite.

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Table 2 - Description of explanatory variables used in the model

<i>Variable</i>	<i>Description</i>	<i>Average</i>	<i>Std. Dev.</i>
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	2.67	1.55
GENDER	1: Male / 0: Female	0.40	0.49
AGE	Age of children between 12-17 years old	14.13	1.62
AUTO	Number of cars in a household	1.01	0.68
NON_AUTO	1: Households with no car / 0: Otherwise	0.21	0.40
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	2.11	1.23
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	0.39
COMFORT	1: If parents are primarily concerned about their children travel comfort / 0: Otherwise	0.18	0.39
DURATION	1: If parents are primarily concerned about their children travel time / 0: Otherwise	0.23	0.42
TRF_LIMIT	1: Students that live or study in a limited traffic zone / 0: Otherwise	0.11	0.31
AUTO_TIME	Automobile travel time to school (minute)	9.91	8.75
SBUS_TIME	School bus travel time to school (minute)	13.23	11.23
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
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
ESCORT	1: If parents accompany their kid to school / 0: Otherwise	0.36	0.48
NORM_COST	Out-of-pocket automobile travel cost (10 Rials) divide by INCOME	212.04	118.84

^{*} 11800 Iranian Rials was equivalent to 1 USD in May 2011.

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Table 3 -Mode choice models

Variables	Alternatives	Multinomial logit		Nested logit	
		Coefficient	t-statistic	Coefficient	t-statistic
Constant	Automobile	-4.91***	-15.10	-7.60***	-5.09
COMFORT		0.47***	2.88	0.83***	2.65
DURATION		1.11***	9.33	1.28***	8.62
AUTO_TIME		-0.03***	-4.16	-0.038***	-4.16
NORM_COST		-0.002***	-4.36	-0.003***	-4.87
AUTO		0.49***	5.01	0.57***	5.10
Constant		School Bus	-4.44***	-7.82	-7.27***
COMFORT	0.78***		4.79	1.16***	3.50
RELIABLE	0.82***		6.35	0.90***	5.87
SBUS_TIME	-0.003		-0.63	-0.01	-1.32
TRF_LIMIT	0.78***		3.22	0.80***	3.12
AGE	-0.114***		-3.21	-0.118***	-2.86
INCOME	0.38***		7.29	0.46***	6.74
Constant	Public	-5.42***	-7.98	-6.54***	-5.13
TRAFIC_LIMIT		2.15***	8.28	2.06***	8.23
AGE		0.11***	2.66	0.12***	2.87
NON_AUTO		1.21***	6.26	1.28***	6.23
EDUCATION		-0.52***	-5.42	-0.54***	-5.70
WALKTRNT		-0.0006***	-4.16	-0.0006***	-3.73
INCOME		-0.23**	-2.49	-0.28***	-2.62
SAFETY		-0.59***	-4.01	-0.59***	-3.82
EDUCATION	Active	-0.28***	-3.90	-0.28***	-3.71
SAFETY		-1.72***	-12.08	-1.68***	-11.45
POPDENS		12.10**	2.54	12.69***	2.68
NON_AUTO		0.95***	5.13	0.94***	4.88
ESCORT		-1.82***	-13.04	-1.82***	-12.12
GENDER		-0.51***	-4.08	-0.53***	-4.20
WALKSCH		-1.27***	-19.04	-1.24***	-16.52
TRAFIC_LIMIT		1.48***	5.51	1.12***	3.96
Inclusive value parameters:					
Non Active				0.78862***	4.95
Active				1.0(fixed)	
Private				0.74299***	4.97
Public				1.0(fixed)	
Log-likelihood at zero		-3404.45		-3404.45	
Log-likelihood at convergence		-2280.40		-2276.70	
McFadden Pseudo R-squared		0.32		0.38	
Sample size		2653		2653	

Note: ***, **, * means significance at 1%, 5%, 10% level

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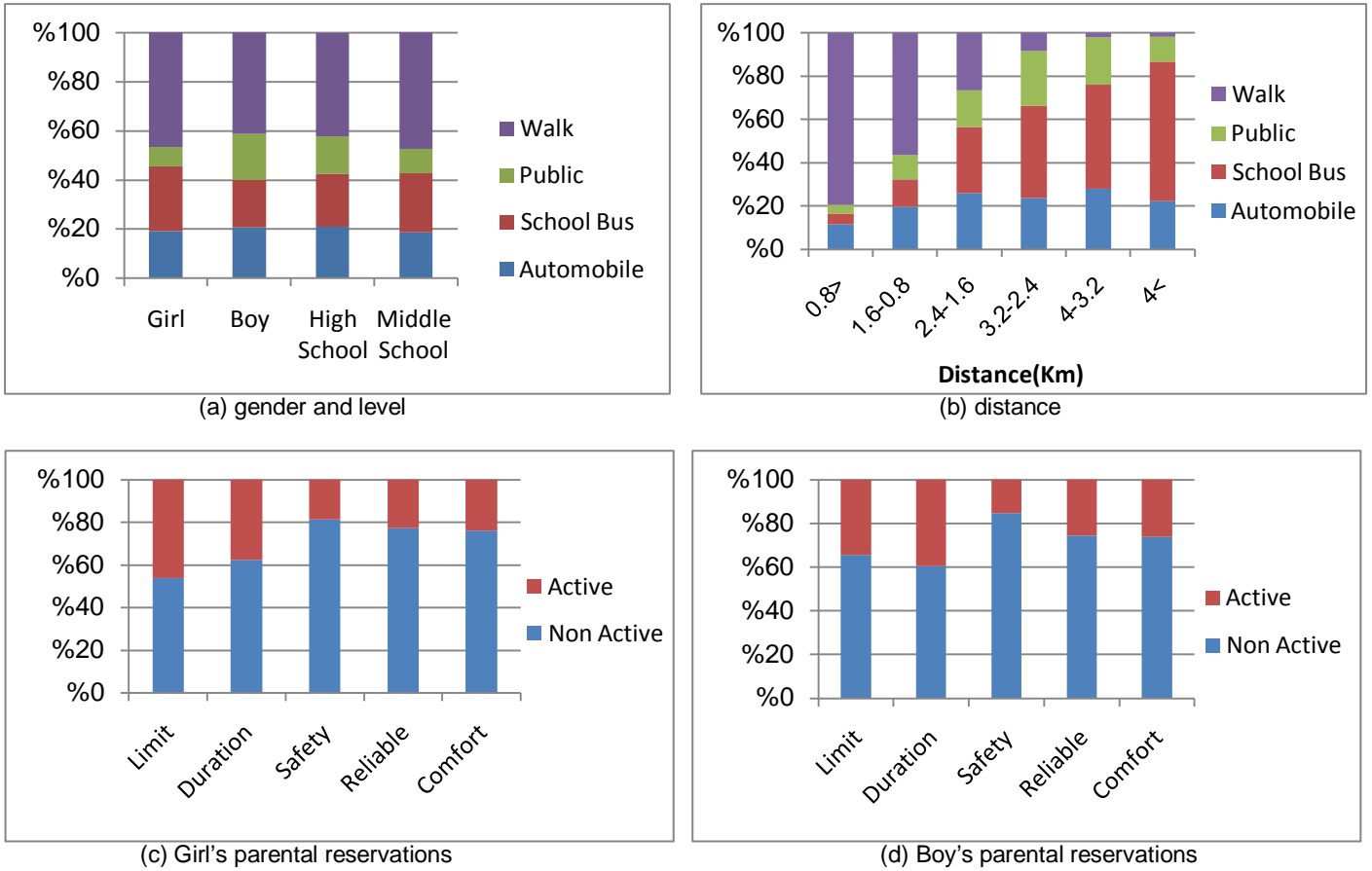


Figure 1- Children's mode choice descriptive

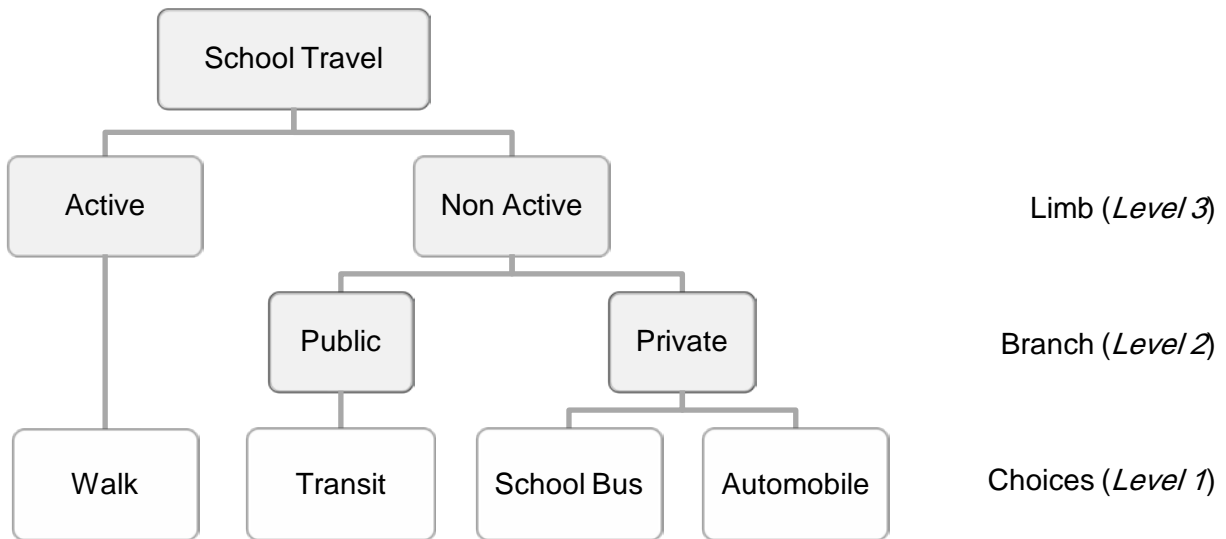


Figure 2 - Tree structure for the nested logit model

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Table 4 -Elasticities for multinomial logit (MNL) and nested logit (NL) models

Attribute	Primary Alternative	Public		Automobile		School Bus		Active	
		MNL	NL	MNL	NL	MNL	NL	MNL	NL
AUTO_TIME	Automobile	0.06	0.06	-0.25	-0.27	0.06	0.10	0.06	0.04
AUTO	Automobile	-0.13	-0.12	0.36	0.36	-0.13	-0.20	-0.13	-0.08
NORM_COST	Automobile	0.10	0.10	-0.41	-0.46	0.10	0.19	0.10	0.07
SBUS_TIME	School Bus	0.01	0.03	0.01	0.05	-0.03	-0.08	0.01	0.02
AGE	Public	1.39	1.52	-0.19	-0.28	-0.19	-0.28	-0.19	-0.17
	School Bus	0.37	0.31	0.37	0.52	-1.23	-1.14	0.37	0.22
INCOME	Public	-0.44	-0.46	0.04	0.06	0.04	0.06	0.04	0.03
	School Bus	-0.25	-0.24	-0.25	-0.37	0.56	0.60	-0.25	-0.17
EDUCATION	Public	-0.97	-0.97	0.11	0.14	0.11	0.14	0.11	0.09
	Active	0.21	0.21	0.21	0.21	0.21	0.21	-0.36	-0.36
WALKTRNT	Public	-0.34	-0.32	0.04	0.05	0.04	0.05	0.04	0.03
POPDENS	Active	-0.14	-0.15	-0.14	-0.15	-0.14	-0.15	0.15	0.15
WALKSCH	Active	0.94	0.91	0.94	0.91	0.94	0.91	-2.44	-2.37

Table 5 -A comparison of elasticities

Variable	Walk			Automobile	
	Ewing	McDonald	Current Study	McDonald	Current Study
Walk Time	-0.66	-0.748	-2.372	0.104	0.918
Auto Time	-	0.010	0.046	-0.078	-0.277
Income	-0.84	-0.255	0.03/-0.17	0.211	0.06/-0.37
Age	-	0.820	-0.17/0.22	-0.577	-0.28/0.52
Population Density	-	0.116	0.158	-0.017	-0.153
Vehicle Ownership	-1.16	-	-0.088	-	0.369

Dissimilarities in culture, demographics, built-environmental factors, and analysis methods are possible reasons for these contradictory findings. A study (Leslie et al., 2010) in Australia, for instance, targeted 2961 ten to fourteen years old students and argued that gender of the kids affect their tendency to walk and bike. Although they found girls to be more willing to walk

(44.3% versus 37.4%), boys were more likely to bike to school (22.4% versus 8.3%). We also found boys more reluctant to walk. This could be due to some female students' willingness to take after school time as an opportunity to socialize with friends and be less constrained for a short while (Samimi and Ermagun, 2012a).

Income, car ownership, and parental education are also recognized in school trip AMT utilization. A negative relationship that income and vehicle ownership have with AMT propensity is widely recognized (McMillan, 2007; McMillan et al., 2006, McDonald, 2008b), although the effect magnitudes are different. Moreover, a dummy variable (*NON_AUTO*) for households with no private car indicates students from such families are, understandably, more likely to walk or take transit to school. Table 4 indicates that one percent increase in the family income reduces likelihood of public transit use by 0.46 percent, and increase chance of driving, walking, and riding on school bus, respectively, by 0.06, 0.03, and 0.06 percent. In accordance with Martin et al. (2007), however, a negative association between parental education level and tendency to use AMT and public transportation was found. This could be attributed either to the positive correlation between income and education, or to the fact that educated parents are more aware of potential risks that exist in walking and taking transit.

Safety, comfort, reliability, and duration of the school trip, along with the school or home being located in a limited traffic zone were found to influence students' modal decisions. The first two factors had been explored in previous studies (McDonald and Aalborg, 2009; McMillan, 2007), while the rest have received very little (Samimi and Ermagun, 2012b), if any, attention. According to Table 3, parents who are concerned about their children's safety are more reluctant to have their kids walk or take transit. Further, parents who are primarily worried about the comfort of their kids are more willing to use the school bus or personal vehicle. School bus is more appealing to those who seek a reliable mode, and traffic restrictions incline students toward public transportation, walking, and school bus. As expected, parents who are concerned about the duration of their kid's travel are more willing to use a personal car. Table 6 provides the reduction in AMT propensity when any of the aforesaid variables becomes one, having all the continuous variables at mean, discrete variables at mode, and other parental reservations at zero. This reduction is reported for male and female students, and also for families with and without an automobile. According to this table, safety has a central role, followed by comfort, and duration. Households with at least one vehicle are much more sensitive to safety, comfort, and duration of the trip.

Table 6 - Percentage of reduction in the likelihood of walking by changing parental reservations

<i>GENDER</i>	<i>NON_AUTO</i>	Parental Reservations			
		Comfort	Duration	Reliability	Safety
Female	With Auto	23	16	10	59
	Without Auto	8	6	4	43
Male	With Auto	24	20	12	66
	Without Auto	12	10	6	53

Policy Implementation

There are some policy sensitive variables in the model that allows the city officials to understand possible ways of promoting active school trips. These variables that include travel time, cost, vehicle ownership, access to public transit, commute distance to school, and students' safety are discussed in the following.

Auto travel time has a direct elasticity of -0.27, according to Table 4. This indicates one percent increase in auto travel time discourages parents from driving their kids to school by a probability of 0.27 percent. Further, this would result in a marginal increase in the share of other modes. Probability of walking, riding a school bus, and public transit, respectively, increases by 0.05, 0.1, and 0.07 percent. A higher sensitivity of automobile mode to the travel time that is arguably relative to congestion level is understandable, as many parents (10 percent) drive their kids to school on their way to work. Travel time of the school bus, on the other hand, has a direct elasticity of -0.08 in the NL models, while this number is about -0.03 in MNL model. This is a direct consequence of model misspecification that leads to an underestimation of automobile use when school bus becomes less appealing. The results indicate that school bus is a likely replacement for private cars, mainly due to the safety and reliability of service. Therefore, it could be considered as a potential alternative for parents who drive their kids to school.

Cost of travel is normalized to household income to consider a systematic taste variation among families. This makes the model outputs more realistic, since low-income and high-income families have different reaction to one dollar increase in their kid's travel cost. In our study, one percent increase in the normalized auto cost decreases the likelihood of driving by 0.46 and 0.23 percent, respectively, for low and high income households. This distinction is essential for assessing policies that aim at reducing auto driving through different pricing scenarios. Furthermore, a direct elasticity of -0.46 for the normalized auto travel cost and indirect elasticities of 0.11, 0.19, and 0.07, respectively, for public, school bus, and walk modes are reported in Table 4. Consequences of model misspecification is evident in this table, as indirect elasticities of public, school bus, and walk modes are all equal to 0.10 in the MNL model. Therefore, expected share of students who walk to school will be over-estimated; if a taxation policy on automobile usage is assessed by a MNL model.

Vehicle ownership has a direct elasticity of 0.37 in the automobile mode. This, arguably, indicates that acquiring a second car in families with one vehicle, increases propensity of automobile use in school trips by 37 percent. As a result, the probabilities of walking and using public transportation decrease by 8.8 and 12.7 percent, respectively. This estimate should only be considered as an approximation, because partial derivatives that are used to calculate elasticities are valid in a small vicinity of the observation point. Expecting a growing trend in vehicle possession, city planners should be alerted of a potential increase in the use of private cars and reducing the share of active transportation modes. An interesting observation in Table 4 that underscores the consequences on model misspecification is that indirect elasticities of vehicle ownership (*AUTO*) is -0.13 in the MNL model, while NL model provides different elasticities of -0.12, -0.20, and -0.08, respectively for public, school bus, and walk modes. This misspecification results in over estimating the reduction in the share of students who walk to school, when vehicle ownership increases.

Access to public transit is a key variable that is recommended in many previous studies to be accounted for in school trip mode choice studies. Distance to the nearest bus station that is located on the way of each student to school was obtained and turned out to have a significant negative effect on public transit usage. Table 4 shows that one percent increase in the distance to the nearest bus station decreases the likelihood of transit usage by 0.33 percent. This would also increase probabilities of auto, school bus, and walk, respectively, by 0.05, 0.05, and 0.03 percent. Again, the MNL model predicts a similar indirect elasticity of 0.04 for all the non-transit modes. Therefore, a misspecification bias slightly over predicts share of students who walk to school instead of taking transit, when access to the public transit system is decreased.

Commute distance to school is, arguably, the most prominent factor that influence walking and biking to school. This parameter has received a central attention in smart development of land-use, and has the highest absolute value of elasticity in our model. Previous studies (Fyhri et al., 2011; Larsen et al., 2009; Ewing et al., 2004; Merom et al., 2006) have unanimously noted a negative correlation between commute distance and use of active modes. We also found a direct elasticity of -2.4 for walk time to school that indicates every one percent increase in the students' commute distance discourages use of active modes by a probability of 2.4 percent. Urban planners argue that schools sprawl can exacerbate urban challenges and make the land-use patterns inefficient (Cole et al., 2010; Passmore, 2002). Some recent guidelines, on the other hand, in the United States required a minimum of 30 acre plus one acre for every 100 high-school students (Schlossberg et al., 2005). This type of regulation urges developers to build schools in urban fringes, in order to acquire enough land and minimize their costs. City planners, therefore, need to be aware of the magnitude of such impacts and must have more contemplation on such policies that discourage active modes of commute to school. Reducing distance to school would increase density of population as well. We found a direct elasticity of 0.16 for population density in the active mode, and an indirect elasticity of -0.15 in the other modes. MNL and NL models, however, predict fairly similar results for this parameter.

Safety is an important concern of parents that is influential on reducing the use of active transportation modes. Our model shows that addressing the safety concerns of parents could increase propensity of active commuting to school by around 60 percent. This increase in the probability of walking is calculated setting the continuous variables at average and discrete variables at their mode. Therefore, planners need to study policies that increase parents' perception about their kids' travel safety to school. Safe Routes to School (McDonald and Aalborg, 2009; Staunton et al., 2003) and Walk School Bus (Collins and Kearns, 2010; Staunton et al., 2003; Engwicht, 1992) are implemented in the United States to address parental safety concerns and improve share of active modes among students.

SUMMARY AND CONCLUSION

This study was an effort to develop a three level nested logit model to explain the behavioral aspects of school trip modal selection. Understanding the motives behind such behaviors is essential for city planners to promote active commuting to school. This is deemed an opportunity to prevent many health issues that are stimulated by a lack of physical activity during childhood. Further, promoting active modes for school trips is an opportunity to decrease the morning peak congestion and thereby mitigate externalities of the transportation system. This study introduced a three level nested logit, and a well-grounded econometric model that deals with strong assumptions of the multinomial logit specification. Although there have been some efforts and recommendations (Ewing et al., 2004) for applying such a model specification, to the best of our knowledge, this is the first model that is introduced to the literature of school trip mode choice. This study looked at a wide range of explanatory variables and conducted an in-depth analysis of the models. Particularly, we underscored the significance of model misspecification in terms of policy outcomes. For instance, elasticity analysis of the MNL model showed an indirect elasticity of vehicle ownership of -0.13 in the MNL model, while NL model provides different elasticities of -0.12, -0.20, and -0.08, respectively for public, school bus, and walk modes. This misspecification results in over estimating the reduction in the share of students who walk to school when vehicle ownership increases. A wide range of policy-sensitive variables along with their effect magnitude was also discussed and compared with the previous studies. Particularly, we found that one percent increase in the probability of walking to school is expected by every 0.046 percent increase in auto travel time, 0.075 percent increase in the normalized-to-income cost of driving, 0.088 percent decrease in vehicle ownership, 0.033 percent increase in distance to public transit, or 2.372 percent decrease in commute distance. Safety was also found to be very influential on active commuting, such that we found addressing the safety concern of parents could increase propensity of active commuting to school by around 60 percent. Yet, this study has the following limitations that could be possible avenues for future research.

- Trips of students who take transit to school should be partially considered as active (Morency et al., 2011), since they need to walk to the nearest bus station. This could be addressed by developing a cross nested logit model, and setting the public transit option in the active limb as well as the *non-active* limb.
- Built-environment variables such as density of green space, school, sidewalk and other land-use variables that are expected to promote walking trips were not utilized, due to unavailability of disaggregate data.
- School trips are the focus of this study, although walking could be promoted in other trips such as shopping and recreational trips.
- A systematic taste variation for cost of travel is considered in this study, while a mixed nested logit specification allows for accounting for a random taste variation. This is expected to provide a more realistic analysis of pricing scenarios.

- Although a dummy variable for parental escort decisions is introduced in the model, the way that children are accompanied to school deserves more attention. A three level nested logit model is presented by the research team (Samimi and Ermagun, 2013) that elaborates choice of “no escort”, “escort by parents”, “escort by others”, and “escort by school bus” on the collected data.

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