THE BUILT ENVIRONMENT, AUTONOMOUS MOBILITY, AND SCHOOL TRAVEL MODE CHOICE IN TORONTO

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Introduction

Urban regions in the developed countries have witnessed a major shift in the way children and youths travel to and from school (Buliung et al., 2009; McDonald, 2007; van der Ploeg et al., 2008). Walking trips have declined over the past decades; more students are now being driven to and from school than ever before. But, physical activity derived from utilitarian sources, such as school travel, may have important implications for the healthy growth and psychological development of children and youths (McMillan, 2007; Transportation Research Board, 2005; Tudor-Locke et al., 2001). Those who regularly walk to school may also appreciate the benefits of sustainable travel practice and active lifestyle in their adult life (Faulkner et al., 2009).

Urban planners and public health professionals have emphasized the importance of an enabling environment that encourages walking school trips. This policy interest has been matched with an emerging literature focused on the potential influence of socio-demographic characteristics and the built environment on mode choice for school travel, particularly on the choice of active modes (i.e., walking and cycling) (see Bere et al., 2008; Ewing et al., 2004; Larsen et al., 2009; McMillan, 2007; Schlossberg et al., 2006). Although the findings from this literature remain inconclusive, exploratory studies have consistently reported that secondary-school age youths (i.e., 14-

15 years) walk and cycle less than those who are younger (Buliung et al., 2009; McDonald, 2007).

Several hypotheses can be proposed that may explain this difference in walking rates. First, secondary schools are larger and are located farther apart than the elementary schools (Buliung et al., 2009); older youths may walk/cycle less due to increased distance between residence and the school. Second, intra-household activity scheduling and joint travel arrangements, that result in a child's/youth's being escorted to school, may partially explain differences in mode choice across age groups. A larger debate exists with regard to the utility of studying children's travel within the household activity-travel framework (Buliung et al., 2009; Copperman & Bhat, 2007), but empirical research on this topic is limited (McDonald, 2008b; Vovsha & Petersen, 2005; Yarlagadda & Srinivasan, 2008). To the authors' knowledge, no study has attempted to explore the relationship between parental escort decision and school travel modes, while also accounting for the built environment characteristics that may influence travel. Speculatively, as children make transition to secondary school age (i.e., grade 9-10), they may become more independent in terms of their travel and mode choice. In contrast, for a younger child, travel mode may often be determined by adult household members, regardless of the escort decision (McMillan, 2005). As a result, preference toward transportation modes can be different for these different sets of population.

This research explores age-related differences in school travel behaviour in the City of Toronto, Canada. The study focuses on children and youths aged 11-12 years and 14-15 years, and investigates two research questions: (1) does household escort decision explain the choice of transportation mode for trips to school? and (2) does the relationship between mode choice, particularly walking, and its correlates vary across age groups? The reminder of the paper is organized into three sections. The next section outlines the study methodology. Empirical findings are described after that, followed by a brief discussion of their policy implications. The paper concludes with a summary of major findings and directions for future research.

Study Design

Data

School travel data were taken from the 2001 Transportation Tomorrow Survey (TTS). The 2001 TTS surveyed 5% of the households in the Sounthern Ontario Municipalities (374,182 persons). A computer assisted telephone interview (CATI) procedure was applied to collect household travel data (e.g., origin/destination of trip, trip start time, purpose, primary mode of transportation) for a randomly selected weekday in the fall or spring of the year (Data Management Group, 2003a; 2008). All trips by household members aged 11 years and older, associated with the day prior to the interview, were proxy reported by an adult household member. The 2001 TTS provided some demographic information of the trip makers' households; variables such as age, sex, number of children in the household, vehicles per licensed driver, and employment status were available.

This research studied home-to-school trips made by children and youths aged 11-15 years (6h00-9h29, interval includes 99.19% of the morning school trips by this age group). Youths aged 16 years and above were excluded from the analysis, based on an assumption that once licensing occurs at the age of 16, the mode choice behaviour may change considerably (Buliung et al., 2009; McDonald, 2008a). In order to be able to explore differences in school travel behaviour across age, two age groups, defined based on the school typology, were included in the analysis. The first group included 11-12 year olds (3,070 trip records), i.e., children likely going to elementary and intermediate schools (grades 6 to 8). The second group included youths aged 14-15 years (3,109 trip records), who likely were attending secondary schools (grades 9 to 12). Youths aged 13 years were dropped from the analysis.

For the purpose of this study, an "escort" trip was defined as a school trip where a child/youth was accompanied on the way to school by a household member(s) of driving age (i.e., 16 years or above). All other school trips were defined as "independent" trips. Also, the survey did not ask for self-reported trip distances. Rather, the straight-line distance between each origin-destination was calculated, and is reported in kilometres.

Table 1 describes the explanatory variables used in the analysis. Land use mix around each residential location was derived from the TTS work-trip data, and aggregated to the scale of traffic analysis zones (TAZ). For each TAZ, distance to Toronto's central business district (CBD) was calculated using Toronto's street network file. This research also explored the effect of neighbourhood level median household income on school travel, obtained from the 2001 population census of Canada. Besides, the walking rate for work and school related trips within each TAZ was included in the mode choice models.

With respect to transportation supply, street network characteristics were measured within a 400m (0.25 mi) straight-line radius around each household location. Assuming a typical walking speed of 4.8 km per hour (i.e., 3 m per hour) (Ewing et al., 2004), the 400 m radius is equivalent to a 5-minute walking distance around a child's/youth's residence location. The Canadian population census boundary file was used to identify the number of street-blocks within each 400m buffer. To calculate intersection density, the DMTI CanMap Route Logistics file was used (subset 6.2, 2002)©.

Model Specification

The study used a multinomial logit model (MNL) to explore school transportation mode choice for trips to school. Given an exhaustive and mutually exclusive set of alternatives, and a set of observed and measurable variables that may influence mode choice, the MNL can estimate the probability of a household's/person's choosing each mode of transportation (Ben-Akiva & Lerman, 1985; Train, 1993). For this research, the known choice-set for a school trip includes four alternatives: walking, using transit of any kind, school bus, and being driven (by household adults or neighbourhood carpool).

Model Estimation

Informed by the school transport literature (Ewing et al., 2004; McDonald, 2008a), it was assumed that beyond a distance of 5 km (i.e., a 1-hour walk for a child/youth), the choice set becomes restricted to motorized transportation modes only. Therefore, only children and youths living within 5 km (3 mi) from their school were considered for modeling purposes. Adjusting for missing data and outliers, the final dataset included 2,655 home-to-school trips and related records for the 11-12 years age group, and 2,305 such records for the 14-15 years age group.

TABLE 1 Socio-Demographic, Built Environment and Escort Variables

Socio-Demographic Variables
SEX: Sex of a child (0 if female, 1 if male)
CHILDREN: Number of 4-15 year-old children in a household (i.e., school-age children below the driving age)
VEH_LIC: Number of vehicles in the household per licensed driver
FUL_EMP: Number of full-time employees per adult household member (ages 18 to 65 years)
Built Environment Variables
DISTANCE: Straight-line trip distance between the residence and school (Km)
EMP_BAL: The ratio of retail/service/manufacturing/ trade/ office/ professional employment and population in the TAZ
4WAYNODES: Number of street intersections (4 way) within 400 m radius
BLOCK: Number of street-blocks within 400m radius
DIST_CBD: Distance between Toronto CBD and the TAZ
MEDHHINC: Median household income of the DA
WALK_TOT: Total work/school related walk trips that occur per sq. km. of area, in the TAZ
Escort Variable
ESCORT: A child/youth is traveling to school with a household adult aged 18 years and above (0 if escort trip, 1 if independent trip)

NOTE:

a. All built environment variables were measured at the location of a household’s residence, geo-coded using the postal address.
b. TAZ- Traffic Analysis Zone (2001 TTS), DA- Dissemination Area (Canadian Population Census).

A total of fifteen explanatory variables were initially considered for the multivariate analysis. Following Lee & Moudon (2006), and prior to specifying the MNL model, the built environment and socio-economic variables were filtered using a two-stage screening process. First, the degree of correlation between each of these potential explanatory variables and the likelihood of walking was tested using bivariate logistic regression; only those variables holding a statistical significance at $p \leq 0.10$, and showing the expected *sign,* were included in the next step. Second, a correlation analysis was conducted to test for co-linearity between the built environment variables.

Two sets of MNLs were estimated in the final analysis to explore mode choice behaviour across the two age groups. The private automobile (i.e., driven in a car) was used as the reference mode, and the un-confounded influence of each of the socio-demographic, built environment, and escort variables on the odds of walk, transit and schoolbus modes over driving was reported. However, since this research is particularly focused on active school trips (i.e., walking), findings with regard to walking behaviour are discussed in greater detail.

Findings

School transportation mode shares in the City of Toronto, for the two sample age groups, are summarised in Table 2. The table shows that less than one-fifth of the students were escorted to school by household adult(s), which is considerably lower than what has been observed in the US (McDonald, 2008b). Also, escort trips were almost exclusively made by private automobiles. In contrast, independent school trips (i.e., trips where no household adult accompanied the students) were predominantly walking trips. However, 8% of all children and youths were driven to school by adults who did not belong to their households. Although this finding may contradict *a priori* expectations regarding the exclusive role of household adults as caregivers, it is consistent with observations made elsewhere (McDonald, 2008b, Weston, 2005), and to some extent, demonstrates the complex nature of the intra and inter-household interactions with respect to school transportation. These students were probably driven by family-friends, neighbours, or other family members who did not live in the same household.

TABLE 2 Mode Choice By Age Group

	11-12 years (n= 2,655)			14-15 years (n=2,305)		
	Total Trip		%	Total Trip		%
Walk						
Escort	6		0.23	2		0.09
Independent		1505	56.69		1002	43.46
Transit						
Escort	0		0.00	0		0.00
Independent		228	8.59		708	30.72
Schoolbus						
Escort	0		0.00	0		0.00
Independent		251	9.45		47	2.04
Auto						
Escort	46		17.36	35		15.53
	1			8		
Independent		204	7.68		188	8.16
Total			**100**			**100**
Escort	46		17.59	36		15.62
	7			0		
Independent		2188	82.41		1945	84.38

Table 2 also indicates some differences in mode choice across the two age groups. Older youths (i.e., 14-15 years) used transit more often when traveling independently, compared to younger children, while the 11-12 year olds were more likely to take a school bus than use transit, when not traveling with household adults. The remainder of this section introduces the multivariate logistic regression results; summarised in Table 3 (11-12 years) and Table 4 (14-15 years). Overall, the estimation results suggest that, for both age groups, household travel interaction, more particularly, escort vs. independent trips, moderated mode choice. Also, including ESCORT as an explanatory variable considerably improved the model fit. For example, the McFadden ρ^2 (adjusted) of the MNL specified for the 11-12 year olds increased from 0.22 to 0.43, as a result of including ESCORT as a variable. For the 14-15 years age group, the adjusted ρ^2 value increased from 0.27 to 0.48.

The multivariate analysis indicates that when children and youths were traveling independently (i.e., alone, with siblings, or with non-household members), the odds of walking compared to being driven were significantly higher. This finding is not entirely surprising, given our previous observation that suggested associations between escort trips and driving, and between independent trips and walking (Table 2). To understand the correlation between independent trips and other modes of travel (i.e., transit and school bus), across the age groups, we plotted the un-confounded effects of the ESCORT variable on mode choice (Figure 1). Consistent with our previous findings, the figure reveals that regardless of socio-demographic composition,

TABLE 3 Correlates of School Travel Modes- 11-12 Years Age Group

	Walk		Transit		Schoolbus	
	Coef. (S.E.)	OR (95% CI)	Coef. (S.E.)	OR (95% CI)	Coef. (S.E.)	OR (95% CI)
SEX (Male)	0.05	1.06	0.05	1.05	0.22	1.24
	(0.16)	(0.77-1.44)	(0.20)	(0.71-1.56)	(0.19)	(0.85-1.80)
CHILDREN	-0.08	0.92	-0.13	0.88	0.01	1.24
	(0.10)	(0.77-1.11)	(0.12)	(0.70-1.11)	(0.19)	(0.85-1.80)
VEH_LIC	**-0.54**	**0.58**	**-1.10**	**0.33**	*-0.32*	*0.73*
	(0.21)	**(0.39-0.87)**	**(0.26)**	**(0.20-0.55)**	*((0.24)*	*(0.45-1.17)*
FUL_EMP	*0.43*	*1.54*	-0.20	0.82	*-0.42*	*0.66*
	(0.27)	*(0.91-2.60)*	(0.33)	(0.43-1.56)	*(0.32)*	*(0.35-1.23)*
DISTANCE	**-1.59**	**0.20**	**0.41**	**1.51**	**0.17**	**1.18**
	(0.11)	**(0.17-0.25)**	**(0.09)**	**(1.26-1.82)**	**(0.09)**	**(0.99-1.41)**
EMP_BAL	-0.13	0.88	0.19	1.21	-0.02	0.98
	(0.20)	(0.60-1.31)	(0.24)	(0.76-1.92)	(0.25)	(0.60-1.60)
4WAYNODE	-0.01	0.99	*-0.04*	*0.96*	0.01	1.01
	(0.03)	(0.94-1.04)	*(0.03)*	*(0.90-1.02)*	(0.03)	(0.95-1.07)
BLOCK	0.02	1.02	0.03	1.03	-0.02	0.98
	(0.02)	(0.98-1.06)	(0.03)	(0.98-1.08)	(0.03)	(0.93-1.03)
DIST_CBD	-0.00	1.00	-0.00	1.00	0.00	1.00
	(0.00)	(1.00-1.00)	(0.00)	(1.00-1.00)	(0.00)	(1.00-1.00)
MEDHHINC	-0.00	1.00	**-0.00**	**1.00**	**-0.00**	**1.00**
	(0.00)	(1.00-1.00)	**(0.00)**	**(1.00-1.00)**	**(0.00)**	**(1.00-1.00)**
WALK_SKM	**0.00**	**1.00**	**0.00**	**1.00**	**0.00**	**1.00**
	(0.00)	**(1.00-1.00)**	**(0.00)**	**(1.00-1.00)**	**(0.00)**	**(1.00-1.00)**
ESCORT	**6.43**	**620.79**	16.85		17.10	
	(0.45)	**(257-1496)**	(130.59)	-	(135.67)	-
Intercept	**-2.66**	**0.07**	-15.89		-16.62	
	(0.72)	**(0.02-0.29)**	(130.59)	-	(135.67)	-
Summary Statistics						
Number of Cases: n			2655			
Null Deviance: -2L(0)			5848.19 (DF=7962)			
Residual Deviance: -2L(B)			3352.811 (DF=7926)			
-2[L(0)-L(B)]: χ^2			2495.38			
McFadden ρ^2			0.43; 0.43 (adj.)			

NOTE:

a. Coefficients in **bold** are significant at $p \leq 0.05$.
b. Coefficients in *italics* are significant at $p \leq 0.10$.
c. “-“ represents large number.

TABLE 4 Correlates of School Travel Modes- 14-15 Years Age group

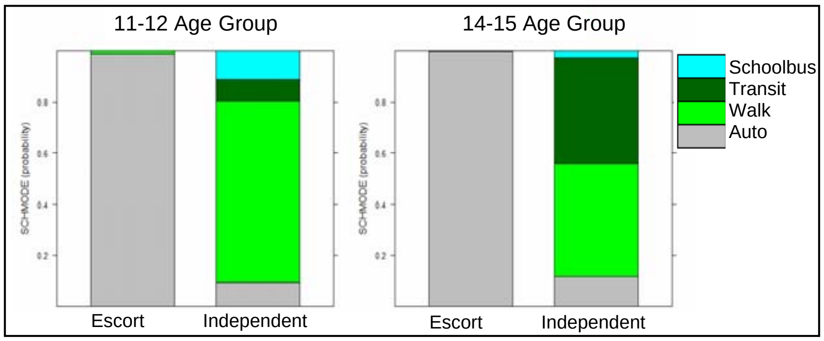
	ESCORT Model					
	Walk		Transit		Schoolbus	
	Coef. (S.E.)	OR (95% CI)	Coef. (S.E.)	OR (95% CI)	Coef. (S.E.)	OR (95% CI)
SEX (Male)	**0.33**	**1.39**	*0.26*	*1.29*	**1.04**	**2.83**
	(0.18)	**(0.98-1.98)**	*(0.17)*	*(0.93-1.80)*	**(0.36)**	**(1.40-5.72)**
CHILDREN	-0.07	0.94	0.02	1.02	-0.01	0.99
	(0.11)	(0.76-1.16)	(0.10)	(0.84-1.24)	(0.20)	(0.67-1.46)
VEH_LIC	-0.27	0.76	**-0.40**	**0.67**	0.05	1.05
	(0.23)	(0.48-1.20)	**(0.22)**	**(0.43-1.04)**	(0.43)	(0.46-2.42)
FUL_EMP	**0.52**	**1.68**	0.29	1.34	-0.08	0.92
	(0.31)	**(0.92-3.07)**	(0.30)	(0.75-2.40)	(0.58)	(0.29-2.88)
DISTANCE	**-1.88**	**0.15**	**0.31**	**1.36**	0.09	1.10
	(0.11)	**(0.12-0.19)**	**(0.09)**	**(1.15-1.60)**	(0.06)	(0.80-1.51)
EMP_BAL	**-0.48**	**0.62**	*-0.31*	*0.73*	*0.07*	*1.08*
	(0.27)	**(0.36-1.06)**	*(0.22)*	*(0.47-1.13)*	*(0.36)*	*(0.54-2.16)*
4WAYNODE	**-0.01**	**0.99**	**-0.06**	**0.94**	-0.06	0.94
	(0.03)	**(0.94-1.05)**	**(0.03)**	**(0.89-0.99)**	(0.05)	(0.85-1.04)
BLOCK	-0.01	0.99	0.01	1.01	0.07	1.07
	(0.02)	(0.95-1.04)	(0.02)	(0.97-1.06)	(0.04)	(0.99-1.17)
DIST_CBD	*-0.00*	*1.00*	**-0.00**	**1.00**	0.00	1.00
	(0.00)	*(1.00-1.00)*	**(0.00)**	**(1.00-1.00)**	(0.00)	(1.00-1.00)
MEDHHINC	-0.00	1.00	**-0.00**	**1.00**	-0.00	1.00
	(0.00)	(1.00-1.00)	**(0.00)**	**(1.00-1.00)**	(0.00)	(1.00-1.00)
WALK_SKM	**0.00**	**1.00**	**0.00**	**1.00**	0.00	1.00
	(0.00)	**(1.00-1.00)**	**(0.00)**	**(1.00-1.00)**	(0.00)	(1.00-1.00)
ESCORT	**7.17**	**1297.25**	18.10		15.65	
	(0.73)	**(307-5467)**	(127.89)	-	(154.63)	-
Intercept	**-2.45**	**0.09**	-15.76		-18.23	
	(0.97)	**(0.01-0.57)**	(127.90)	-	(154.63)	-
Summary Statistics						
Number of Cases: n			2305			
Null Deviance: -2L(0)			5278.89 (DF=6912)			
Residual Deviance: -2L(B)			2772.14 (DF=6876)			
-2[L(0)-L(B)]: χ^2			2506.75			
McFadden ρ^2			0.47; 0.48 (adj.)			

NOTE:

a. Coefficients in **bold** are significant at *p≤0.05.*
b. Coefficients in *italics* are significant at *p≤0.10.*
c. "-" represents large number.

distance, and the built environment near the residence, 14-15 year olds were less likely to walk, and more likely to use transit for their trips to school, compared to the younger children. In contrast, 11-12 year olds were more likely to take schoolbus when traveling independently to school compared to the older youths.

FIGURE 1 Effect Plots Showing Un-confounded Correlation between Escort vs. Independent Trips and Mode Choice



In addition to ESCORT, the effects of other socio-demographic and built environment correlates on mode choice also appear to differ across the two age groups (Tables 3 and 4). For the 11-12 years age group, a child's sex did not associate with mode choice; whereas males among the 14-15 year olds were more likely to walk (than be driven) to school. Increased access to private automobiles reduced the probability of walking among younger children, while for older youths, a household's access to automobiles was not associated with walking. The existing literature has reported that if the parents are employed full time, and travel to work in the morning, the likelihood that a student walks to school decreases (McDonald, 2008b; Yarlagadda & Srinivasan, 2008). For our sample, however, household adults' employment rate (i.e., number of full-time employed persons per adult household member) was positively correlated with walking, for both age groups.

In line with the past research, this study found a strong negative association between distance to school and the probability of walking for school transportation (Black et al., 2001; Ewing et al., 2004; McDonald, 2008a; Schlossberg et al., 2006). Beyond distance, the influence of the built environment on walking was more pronounced for 14-15 year olds than 11-12 year olds (Tables 3 and 4). A 14-15 year old student was less likely to walk to school if the neighbourhood of residence had more employment (i.e., more land use mix, and therefore, perhaps busier), was farther from the central city (i.e., "suburban style" urban design), and had more 4-way intersections (i.e., less traffic safety, actual or perceived). Also, youths were more likely to walk if others in the neighbourhood were also walking for work and/or school purposes. For 11-12 year olds, however, the only aspect of the built environment that influenced walking was WALK_SKM (i.e., more people walking), implying that a child of this age was more likely to walk if the walking rate for the TAZ of residence was relatively high.

Discussion

Overall, this study begins to provide new insights into the understanding of school transportation behaviour. Journey-to-school mode choice is strongly associated with intra-household interaction with regard to travel, which may include issues surrounding the negotiation of access to household automobiles, or the scheduling of work or other activities of household adults. For older youths, however, the nature of interaction with the built environment likely has a stronger influence on mode choice, compared to the younger age group. The observed difference across age groups hints toward the potential role of independent mobility in the choice of school transportation modes. Younger children seemingly are only "allowed" to walk when adults are unable to escort them to school themselves or with the help of others, or are motivated toward walking as a preferred mode for school transportation. Transit receives fewer trips from children, perhaps due to the perceived incapability of these children to interact with the public transportation system. In contrast, older youths seem to travel more independently, and thus, the quality of the neighbourhood built environment matters in their mode choice decision. But, when providing an option between walking and transit, many opt to use transit instead of walking.

Findings from this research can inform urban policy development in two ways. First, intervention into the built environment alone does not seem to be an effective tool to encourage walking among children and the youth; and second, it appears that policies should target both parents and children/youths, as both perform their roles in mode choice decisions at difference stages of a child's student life. Policy emphases in the fields of public health and urban planning have largely been different with respect to the promotion of active transportation. While health practitioners, as well as the community based organizations, are interested in school or community level educational promotions, urban planners primarily focus on creating walking-friendly built environments to enable walking among children and youths. There is clearly a need for these professions/organizations to come together in order to formulate comprehensive and useful policy, that can motivate parents/caregivers and children to first "consider", and then undertake, walking for the purpose of school transportation. The policies should also be specific to a student's age, given that the relative influences of household and the built environment on mode choice likely change with a child's age.

Conclusion

This research explored mode choice for school transportation for children (ages 11-12) and youths (ages 14-15) in the City of Toronto, Canada. Attention was brought upon how the correlates of school travel mode choice vary by age group. Several key findings emerged from both descriptive and the multivariate analyses: (1) that household joint travel arrangements (i.e., escort vs. independent trips) influenced walking as a mode for school transportation, (2) that when traveling independently, mode choice varied across age groups; younger children were more likely to walk than the older youths, and (3) that the influence of socio-demographic characteristics of a household were stronger on a younger child's mode choice when compared with older youths, while the built environment qualities associated more readily with youth travel to school.

The study was motivated by the potential health benefits of walking as a mode for school travel. In response to the current activity-travel debate in school transportation literature (Buliung et al., 2009; McDonald, 2008b; Yarlagadda & Srinivasan, 2008), one aspect of the household travel interaction, i.e., escorting vs. independent trips, was introduced to improve our understanding of school travel behaviour. However, understanding the role of autonomous mobility is but one aspect of understanding school transportation. We anticipate that these findings, combined with the evidence from other empirical research, will improve our knowledge of school transportation behaviour, and help the development of effective policies targeted at active school commuting and physical activity for children and the youth.

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