Built Environment and School Travel Mode Choice in Toronto, Canada

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Walking to or from school may provide a regular source of physical activity for children and youth. To improve walking practices among this younger population, urban planners emphasize the importance of built environment interventions. Empirical understanding of the potential relationship between the built environment and active school transportation (e.g., walking) is therefore essential to the development of effective planning interventions. In the nexus of empiricism and policy, place-based differences in school transport policy and urbanization processes, which may associate with mode choice, provide the rationale for conducting local research to support local policy development. This study examines the association between the built environment and the likelihood of walking or being driven to or from school. The research also addresses differences in mode choice behavior across morning and afternoon school trips. Binomial logit models were specified to study the school travel outcomes of children aged 11 to 13 years in the city of Toronto, Canada. Distance between the residence and school had the strongest correlation with mode choice; other built environment measures had moderate associations with walking. Importantly, the built environment around a child's residence had a stronger association with mode choice than did the built environment around the school. Furthermore, the effect of the built environment was more apparent for home-to-school trips. This research provides evidence that the built environment may influence school travel mode choice, but planners and community-based organizations should exercise caution when the nature of interventions required to encourage walking among children is determined.

Attending school is the most common reason children and youth travel during weekdays in the school year (*1, 2*). For these young people, the use of active transportation modes, such as walking or cycling, for school travel may provide a consistent source of physical activity. As childhood obesity rates rise across North America (*3, 4*), researchers, governments, and practitioners have acknowledged the importance of walking and cycling in preventing excessive weight gain (*2, 5–8*). Perhaps what is more important is that lifelong patterns of physical activity be established in childhood; and speculatively, children who are regularly driven to and from school could be less likely to appreciate the benefits of an active lifestyle into adulthood (*7, 9*). Public health and planning interventions tailored to promote the use of active transportation at an earlier stage of childhood development could provide a mechanism to encourage lifelong patterns of active mobility, acting as a preventive force against the rising tide of overweight and obesity in children and youth.

Urban land use and transport planners have responded to this policy debate by occasionally questioning, and in some cases accepting as conventional wisdom, that the built environment directly influences travel decisions. In the United States, for example, the Safe Routes to School (SR2S) program advocates improving the built environment along school routes and enhancing pedestrian and bicycle facilities (*10*). More recently, the draft Leadership in Energy and Environmental Design for Neighborhood Development rating system requires that compact and mixed-use neighborhoods be located close to schools to promote walking among children (*11*). In Canada, the Ontario Professional Planners Institute has argued that the practice of transport and land use planning should place the needs of children on a par with the needs of other demographic cohorts and businesses (*2, 12*). This emerging child- and youth-friendly turn in planning practice has arguably occurred in advance of conclusive and generalizable knowledge about the relationship between children, youth, the built environment, and travel demand (*13*).

The research described here explores school transportation in the city of Toronto, Canada, and contributes to the emerging school transport literature by examining two research questions:

- What is the association between the built environment and a child's likelihood of walking or being driven to or from school?
- Are there any differences in what and how built environment characteristics correlate with school travel mode choice across morning (home-to-school) and afternoon (school-to-home) trips?

The majority of school travel studies examine trips to school (*13–16*). Drawing a distinction between morning and afternoon school travel (i.e., trips to and from school) and attempting to expose the differential effects of school travel correlates across the two time periods are important, given consistent reports of more walking from school to home in the afternoon (*17–19*). The diagnosis of differential effects across time suggests that planning interventions could produce unintended results at different points in time.

This research will advance the understanding of the relationship between the built environment and school travel mode choice and will also provide critically important, policy-relevant data on school travel in the Canadian context. This last issue is important on two fronts: first, the work represents the beginning of a process aimed at looking at school travel through a comparative lens, with a view to assessing the generalizability of findings from school travel studies conducted in the United States; and second, this research begins to develop domestic knowledge on the subject of school travel to inform

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policy development in the city of Toronto. Findings from this study could assist urban planners, health practitioners, and community-based organizations who are interested in developing and understanding the efficacy of built environment interventions intended to encourage active school travel.

SCHOOL TRAVEL AND THE BUILT ENVIRONMENT

School location has played a central role in the conceptualization of planned neighborhoods in the United States since the 1920s and in Canada beginning with the neighborhood plans of the World War II years, which would later be followed by the corporate suburbs of the postwar era (*20, 21*). Close proximity between the school and residential locations and safety from motorized traffic are two conceptual properties of the planned neighborhood that may have implications for a child's mobility and mode choice within a neighborhood. Empirical studies of school travel mode choice have often reported distance and travel cost to be the most important correlates of a child's mode for school transportation (*14–16, 19, 22–24*). Findings appear to be mixed about the influence of street connectivity and traffic safety on mode choice. Some researchers have reported walking to be positively associated with the availability of sidewalks (*15, 25*), intersection density (*19*), and parental attitudes toward safety (*13, 23, 25*), whereas others have found evidence to the contrary (*13, 18*).

With regard to other built environment characteristics, some studies indicated that walking is more likely among children living in dense (*16, 24*), mixed-use (*13, 18*) and street-oriented neighborhoods (i.e., houses with street-facing windows) (*13*); others found few links between the built environment and children's mobility (*15, 18, 24*). It is conceivable that dense, mixed-use, pedestrian-friendly environments influence adult walking for discretionary trips by providing more destinations close by (i.e., an increase in accessibility), reduce overall travel distance, and make the pedestrian trip psychologically more attractive. But given that both the school location and school travel routes are relatively fixed, it remains less clear how the built environment may enable school-related walking. School transportation research requires the development of a theoretical foundation that is not entirely bound up in what is known about the travel behavior of adults. On the basis of current empirical evidence and informed somewhat by theoretical research on both adults' and children's travel (*13, 26*), five conceptual domains were identified to articulate the ways in which the built environment may moderate the decision to take an active mode (i.e., walking) to and from school (Table 1).

STUDY DESIGN

The purpose of this research is to explore the association between the built environment and a child's likelihood of walking or being driven to or from school. The general hypothesis is that after household and personal characteristics are controlled for, the built environment remains an important contributing factor in determining whether a child is walking or being driven on the way to school or on his or her way home. Failure to reject this hypothesis could provide some evidence that planning interventions into the built environment may increase walking among children and youth.

TABLE 1 Built Environment and Active School Travel: Hypothetical Domains

Conceptual Domain	Description
Cost	Distance between home and school appears to influence school travel mode choice. The odds of walking decrease with travel distance.
Connectivity	Better connectivity between home and the school may provide a more direct route to school and reduce travel distance. For example, smaller residential blocks, an interconnected street network (e.g., four-way intersections), and the availability of sidewalks may present households with an enabling environment, one that encourages more walking among children. Mixed land use provides connectivity between destinations, and increases the options for trip chaining, which may be particularly important in determining mode choice when a child is traveling with parents or caregivers.
Traffic and pedestrian safety	Traffic and personal safety concerns are often reported as major barriers to a child's walking to and from school. Sidewalks may enhance the perception of traffic safety, while busy streets and (busy) intersections could discourage walking. Personal safety is relatively difficult to measure objectively and is often indirectly manifested through social qualities of the neighborhood environment. For example, a child (or the parents or caregivers) may walk more if other people are walking on neighborhood streets. Although North American research is scarce, Waygood and Kitamura's (*27*) study of children in Osaka, Japan, found that the likelihood of independent mobility increased with the odds of coming across known persons on streets. The quantity and quality of the land use mix (e.g., number and urban design aspects) may also influence a child's walking. The presence of street-level retail in the neighborhood places "eyes on street" and may increase pedestrian comfort. Larger retail centers or employment districts, on the contrary, may discourage walking school trips, particularly when a child is not accompanied by an adult, due to both traffic (e.g., too busy, too many vehicles) and personal safety (e.g., "stranger danger") concerns.
Comfort and enjoyment	Travel route aesthetics may encourage walking (escorted or otherwise) over automobile use (*25*). Presence of open space or parks along routes to and from school, tree-lined streets, smaller neighborhood blocks, and pedestrian-oriented buildings and houses, for example, may enhance the enjoyment of walking or make it easier to navigate the built environment between the home and school.
Social capital	Since the 1920s, planners have argued in favor of walking in local streets to encourage social interaction (*20*). The opportunity to produce social capital may be an important yet poorly understood motivation for walking among adults and children. While the social capital motive seems to have resonated through time in planning discourse, empirical research in transportation that has explored the social capital dimension has been relatively scarce (*26, 28*). Some research suggests that a household's intention to develop social capital may be lower within suburban neighborhoods (*26*). With regard to children's travel, Waygood and Kitamura (*27*) argued that land use mix, and more people on streets may increase the level of community cohesion (i.e., perhaps a latent indicator of social capital), which may in turn positively influence a child's independent mobility, and, conceivably, walking.

The city of Toronto was chosen as the study area because of the variability it offers in terms of neighborhoods, which are often identified in both the popular and academic literature as offering built environments that either enable or restrict the use of active transportation for school or other activities. Toronto's urban, inner-suburban, and suburban places have developed alongside the rise of professional planning in Canada and capture some of the nation's earliest experiments with the planned built form (*21*). The pre-1998 city limits include what are typically considered traditional neighborhoods with retail and employment-related land uses located along main streets. A series of near and complete political amalgamations since 1998 brought a mix of modernist suburban neighborhoods into expanded city limits. As a result, residential communities in Toronto now range from compact mixed-use neighborhoods, to single-use high-rise communities, to postwar suburban-style developments.

Within Toronto's diverse built environment, the major school boards (Toronto District School Board and Toronto Catholic District School Board) maintain small school catchment areas; 80% of children 11 to 13 years of age travel less than 3 km (1.86 mi) for school (each way, straight-line distance) (*29*). Since most students live within walking distance of their schools, the diversity of Toronto's residential environment offers an excellent opportunity to explore the influence of the built environment on children's school travel.

Data

School travel data were taken from the 2001 Transportation Tomorrow Survey (TTS), which is a repeated cross-sectional survey of travel behavior conducted in Southern Ontario, Canada, and includes data for the city of Toronto. The 2001 TTS surveyed 5% of the households in the study area. A computer-assisted telephone interview procedure was applied to collect household travel data (e.g., origin and destination of trips, trip start time, purpose, primary mode of transportation) for a randomly selected weekday in the fall or spring of the year (*29, 30*). All trips by household members aged 11 years and older associated with the day before the interview were proxy-reported by an adult household member. The survey did not ask for self-reported trip distances. Rather, straight-line distance between each origin and destination was calculated and is reported in kilometers.

The existing literature on children's school travel patterns in the Greater Toronto Area showed that when compared with older youth, 11- to 13-year-olds tend to walk more for school trips. As a result, this study explored mode choice for children aged 11 to 13 years (*17*). With respect to school travel, the home-to-school trips (the time interval 0600 to 0929 h included 99.5% of the morning trips) and school-to-home trips (the time interval 1400 to 0629 h included 96.5% of the afternoon trips) were extracted from the 2001 TTS data separately, with information on the school travel modes, trip distance, and sociodemographic descriptors for children and their households. The initial data set included 4,009 home-to-school trips and 4,000 school-to-home trips by 3,767 households. Fewer trips were reported in the afternoon period; possible reasons for this discrepancy can include reporting error, the absence of trips during the sampled time interval, or trips made by children elsewhere after school rather than returning directly home.

The 2001 TTS provided some demographic information on the households producing the school trips; variables such as age, sex, number of children in the household, vehicles per licensed driver, and employment status were available (Table 2). Household income data are not included as part of the survey (*31*). Although this limitation is acknowledged, perhaps the potential effect of a household's economic status on school travel modes is indirect, through employment composition of the household and access to vehicles, which were explored in this research. In addition, the overall income composition of the census dissemination area (DA) of a child's residence and school location was included in the analysis. Beyond the expected demographic effects, empirical studies of school travel suggest that the built environment near the household (*18, 25*), near the school (*13, 18*), and along the travel route (*19*) associate with walking mode choice. In this research, and similar to that by Ewing et al. (*15*) and Larsen et al. (*18*), built environment characteristics were explored at the residence and school ends of the trip (Table 2). Each built environment variable can be linked with one or more of the five

TABLE 2 Hypothesized Relationship Between Independent Variables and Walking

Variable	Hypothesized Direction of Relationship
Sociodemographics	
AGE: age of a child (11–13 years)	+
SEX: sex of a child (1 if male, 0 if female)	+
CHILD: number of school-age children below driving age (4–15 years) in the household	+
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)	–
UNEMP: unemployed adult household members (1 if there are any, 0 otherwise)	+
Built Environment	
DISTANCE: straight-line trip distance between the home and school (km)	–
POP_DSTY: population density of the TAZ of a child's residence or school	+
MAJOR: number of major road intersections (3 susp. or 4-way) within a 400-m radius of a child's residence or school location. Major roads include primary highway, secondary highway, and major and arterial roads	–
LOCAL: number of 4-way local street intersections within a 400-m radius of a child's residence or school location. Local streets include local neighborhood roads	+
BLOCK: number of street-blocks within a 400-m radius of a child's residence or school location	+
DIST_CBD: distance between the Toronto CBD and the TAZ of a child's residence or school	–
RET_BAL: ratio of sales and service employment to the population, in the TAZ of a child's residence or school	+/–
JOB_BAL: ratio of manufacturing/trade/office/professional employment to the population, in the TAZ of a child's residence or school	–
MEDHHINC: median household income of the DA of a child's residence or school	–
WALK_DSTY: walking density-total work and school related walking trips produced by residents of a child's home or school TAZ, normalized by per square kilometer of area	+

NOTE: "Residence or school" indicates that the variable has been estimated separately for the home and the school location. TAZ = traffic analysis zone, CBD = central business district, and DA = dissemination area.

conceptual domains of the built environment described in Table 1. Although the social capital concept was not measured directly, the variables DIST_CBD and WALK_DSTY represent the availability (or absence) of environments that may enable the production or maintenance of social capital.

Land use mix around the residence and school was derived by using TTS data on the number of work-trip ends in each traffic analysis zone (TAZ). Within the city of Toronto, the mean size of a TAZ is 1.31 km^2 (0.51 mi^2) with a standard deviation of 0.94 km^2 (0.36 mi^2). The TAZs are typically smaller than the city's designated neighborhood boundaries. Each neighborhood, on average, includes three TAZs, with some variation ($\bar{X} = 3.44$ zones, SD = 2.33 zones). TTS trip data were used to calculate the total number of daily work- and school-related trips taken by all residents living in a TAZ. For each TAZ, distance to Toronto's central business district (CBD) was calculated by using Toronto's street network file, obtained from the DMTI Spatial, Inc. CanMap Route Logistics Subset 6.2 (2002).

In acknowledgment of Toronto's diverse socioeconomic landscape, aggregated household income was studied at a smaller geographic scale than the TAZ; median household income at the scale of census DA was obtained from the 2001 population census of Canada. Street network characteristics (i.e., intersection density, number of street blocks) were measured within a 400-m (0.25-mi) straight-line radius around a child's home and school location. Assuming an average walking speed of 5 km/h (3 mph) (*15, 32*), the 400-m radius is equivalent to a 5-min walking distance around a child's residence or the school. To calculate intersection density, the DMTI CanMap Route Logistics file was used. Using data for urban blocks taken from the 2001 population census of Canada, block density was estimated within a 400-m radial distance of each child's home and school location.

Model Specification

A binomial logit modeling approach was used to comparatively explore the correlates of walking versus driving from home to school in the morning (0600 to 0929 h) and then walking versus driving from school to home in the afternoon (1400 to 1829 h). Although the unobserved effects of walking and cycling modes could be correlated, cycling constitutes only 1.3% of all school trips in Toronto by 11- to 13-year-old children (*17*), and therefore excluding cycling is expected to have little impact on the model results. Furthermore, the purpose of this research is to draw a comparison across transportation modes that are typically the focus of the debate on children's active commuting to school and physical activity. This study did not examine other modes available to children and youth, such as the school bus and public transit. Like other empirical research (*13*), the intention here is to begin in an exploratory rather than predictive mode of inquiry, with a view to exposing the differential effects of the built environment on walking or driving for school travel at different times of day.

Within the adopted econometric modeling framework, a household is assumed to select the mode that maximizes net benefits to themselves when faced with a known set of alternative modes for school transportation (*33, 34*). Given a choice between different feasible modes, the utility function U_{nj} for a particular mode j and child n takes the following form:

$$\begin{aligned} U_{nj} &= \alpha_j + \beta_j X_n + \delta_j Y_n + \gamma_j Z_n + \epsilon_{nj} \\ &= V_{nj} + \epsilon_{nj} \end{aligned}$$

where

α_j = alternative-specific constant for mode j,
X_n = distance between residence and school for child n taking mode j,
Y_n = built environment characteristics around home or school location,
Z_n = sociodemographic characteristics of child n and his or her household,
β, δ, γ = vectors of parameter estimates corresponding with each variable category (e.g., distance, the built environment, and sociodemographics), and
ϵ_{nj} = extreme-value error vector specific to child n and mode j.

V_{nj}, then, is the observed utility of mode j to a child n, which is specified here as the sum of components related to distance, the built environment, and the sociodemographic characteristics. Assuming that the error term ϵ_{nj} is independently and identically distributed (iid) across choice alternatives and households, the probability that a child n chooses mode j from an observed set of alternatives can be expressed by the following equation:

$$P_n(j) = \frac{\exp(V_{nj})}{\sum_{l \in J} \exp(V_{nl})}$$

where J is the known choice set for, in this case, a school trip and includes only two alternatives l, walking or being driven in a private automobile (by household adults or in a neighborhood carpool). In future work, the choice set will be broadened to consider multioccupant modes such as the school bus and public transit.

Model Estimation

Informed by the school transport literature (*15,16*), this research assumed that beyond a distance of 5 km (i.e., a 1-h walk for a child), the choice set becomes restricted to motorized transport only. Therefore, only children living within 5 km (3 mi) from their school were considered for modeling purposes. The same set of households was included for both morning and afternoon school travel to explore potential temporal differences in the association between mode choice and its correlates. After adjustment for missing data and outliers, the final data set included 2,729 home-to-school trips ($n_{\text{walk}} = 1{,}922$ and $n_{\text{car}} = 807$) and 2,712 school-to-home trips ($n_{\text{walk}} = 1{,}901$ and $n_{\text{car}} = 811$).

As discussed earlier, 6 sociodemographic variables and 10 built environment characteristics around each home and school location were initially measured for every school trip (Table 2). Following Lee and Moudon (*35*), the variables were filtered by using a two-stage screening process before multivariate logit estimation. In the first stage, the degree of correlation between each of these potential explanatory variables and the likelihood of walking was tested with bivariate logistic regression (Table 3); only those variables holding a statistical significance of $p \leq .1$ and showing the expected sign were included in the next step of the modeling process.

Three out of six sociodemographic variables and most built environment variables had some correlation with mode choice. However, the directions of the observed relationships were, in some cases, contrary to initial expectations. For example, the number of children in the household (i.e., presence of siblings) was initially expected to positively associate with walking school trips, since this situation likely enables siblings to walk to and from school together. But the

TABLE 3 Bivariate Correlation: Sociodemographics, the Built Environment, and Walking

	Home-to-School Trips		School-to-Home Trips	
Variable	*p*-Value	Direction of Relationship	*p*-Value	Direction of Relationship
AGE (reference: 11 year)				
12 year	.1	+	.05	+
13 year	>.1		>.1	
SEX (reference: female)				
Male	>.1		>.1	
CHILD	.05	–	.05	–
VEH_LIC	.001	–	.001	–
FUL_EMP	>.1		>.1	
UNEMP (reference: 0)				
>0	>.1		>.1	
DISTANCE	.001	–	.001	–
Built Environment at Residence				
POP_DSTY	.001	+	.001	+
MAJOR	.001	+	.001	+
LOCAL	.05	–	.05	–
BLOCK	.001	+	.001	+
DIST_CBD	.01	–	.05	–
RET_BAL (reference: <0.1)				
>0.1	.01	–	.01	–
JOB_BAL (reference: <0.5)	.001	–	.001	–
Between 0.5 and 1.5				
>1.5	>.1		>.1	
MEDHHINC	.001	–	.001	–
WALK_DSTY	.001	+	.001	+
Built Environment at School				
POP_DSTY	.001	+	.001	+
MAJOR	.1	+	.1	+
LOCAL	>.1		>.1	
BLOCK	.001	+	.001	+
DIST_CBD	.05	–	.05	–
RET_BAL (reference: <0.1)				
>0.1	.001	–	.001	–
JOB_BAL (reference: <0.5)	.001	–	.001	–
Between 0.5 and 1.5				
>1.5	>.1		>.1	
MEDHHINC	.001	–	.001	–
WALK_DSTY	.001	+	.001	+

NOTE: Variables in italics were excluded in the multivariate logistic regression specification.

bivariate regression demonstrated the opposite result. Although unexpected, this finding is not surprising, and at least one other North American study has found similar results (*22*). Perhaps the finding reflects the contemporary Western culture of idealized motherhood, in which there is less recognition and trust for the capability of siblings as caregivers (e.g., travel companions) to their younger brothers and sisters (*36*). In a household with more than one child, driving instead of walking to and from school may also be the preferred option for parents from the perspective of value of time and convenience, particularly when children attend different schools.

With respect to street design, although the density of four-way local street intersections (LOCAL) was initially expected to associate with more walking, a negative correlation was observed. This result could suggest that the reduced traffic safety imposed by more street crossings is more important in the mode choice decision than the improvements in connectivity that they offer. In contrast, intersection density of major streets (MAJOR) was positively associated with the likelihood of walking, contrary to the initial expectation of a negative correlation. Many of the larger intersections (i.e., four-way intersections of major streets) are likely signalized, offering a sense of safety that may encourage walking. Although such a hypothesis may partly explain the observed correlation, overall, this positive bivariate association was counterintuitive, and for this reason, the variable MAJOR was removed from further analysis.

The second stage of the filtering process involved an examination of multicollinearity across variables. Since most of the sampled students live close to their schools, the built environment variables around the residence and near the school were highly correlated ($r \geq 0.70$ in most cases). To date, the spatial correlation of the built environment variables between the school and home trip ends has received little attention in the literature. Ewing et al. (*15*) considered the average built environment across the school and home locations. Lee and Moudon (*35*) dealt with the issue more explicitly, but in the context of adult walking. In this study, to overcome the collinearity problem, separate models were specified and estimated, one for the built environment variables around the residence and the other for the school. The correlation between built environment variables at the home or school end was weaker than was the case when no variable distinction was made by location. The only exception was the TAZ population density (POP_DSTY), which, for both the residence and school, was strongly associated ($r > 0.85$) with walking density (WALK_DSTY). Population density is often used in urban form–transportation research as an omnibus indicator of the combined effect of access and land use mix; these more specific built environment characteristics were included in this analysis as independent variables (Table 2). As a result, POP_DSTY was excluded in the final model specification.

In the end, two sets of binomial logit models were estimated to explore the effects of the built environment on the choice between walking and being driven. The first set of models examined a child's morning period (0600 to 0929 h) home-to-school trips, and the second set explored mode choice for the afternoon period (1400 to 1829 h) school-to-home trips. Within each time period, models were also estimated separately to examine home and school-end effects. The private automobile was used as the reference mode, and the unconfounded influence of each of the sociodemographic and built environment variables on the odds of walking over driving is reported.

RESULTS AND DISCUSSION

The logistic regression results are summarized in Tables 4 and 5. The convergence of the models was satisfactory; adding built environment variables to an initially specified model with only sociodemographic

TABLE 4 Binomial Logistic Regression for Walking: Home-to-School Trips

	Home Model				School Model			
Variable	Coeff.	Standard Error	*p*-Value	Odds Ratio for Walking (95% CI)	Coeff.	Standard Error	*p*-Value	Odds Ratio for Walking (95% CI)
AGE (ref.: 11 year)								
12 year	**0.28**	**0.12**	**.02**	**1.32 (1.05–1.67)**	**0.29**	**0.12**	**.01**	**1.33 (1.06–1.68)**
13 year	0.22	0.12	.08	1.24 (0.98–1.58)	0.21	0.12	.09	1.23 (0.97–1.56)
CHILD	−0.09	0.06	.16	0.92 (0.81–1.03)	−0.09	0.06	.15	0.91 (0.81–1.03)
VEH_LIC	**−0.92**	**0.12**	**.00**	**0.40 (0.31–0.51)**	**−1.01**	**0.12**	**.00**	**0.36 (0.29–0.46)**
DISTANCE	**−1.26**	**0.07**	**.00**	**0.29 (0.25–0.33)**	**−1.26**	**0.07**	**.00**	**0.28 (0.25–0.32)**
Built Environment at Residence								
LOCAL	−0.03	0.02	.13	0.97 (0.94–1.01)				
BLOCK	**0.05**	**0.02**	**.03**	**1.05 (1.00–1.09)**				
DIST_CBD	0.00	0.00	.26	1.00 (0.99–1.00)				
BLOCK*DIST_CBD	**−0.00**	**0.00**	**.02**	**0.99 (0.99–0.99)**				
RET_BAL (ref.: <.1)								
>0.1	0.29	0.32	.36	1.34 (0.72–2.49)				
JOB_BAL (ref.: <0.5)								
0.5<job/pop<1.5	**−0.81**	**0.34**	**.02**	**0.44 (0.23–0.87)**				
>1.5	−0.06	0.64	.93	0.96 (0.27–3.30)				
MEDHHINC	**−0.00**	**0.00**	**.00**	**0.99 (0.99–0.99)**				
WALK_DSTY	**0.00**	**0.00**	**.04**	**1.00 (1.00–1.00)**				
Built Environment at School								
BLOCK					0.01	0.02	.59	1.01 (0.97–1.05)
DIST_CBD					0.00	0.00	.69	1.00 (0.99–1.00)
BLOCK*DIST_CBD					−0.00	0.00	.26	0.99 (0.99–1.00)
RET_BAL (ref.: <.1)								
>0.1					−0.25	0.21	.25	0.78 (0.51–1.19)
JOB_BAL (ref.: <0.5)								
0.5<job/pop<1.5					**−0.51**	**0.21**	**.01**	**0.60 (0.40–0.90)**
>1.5					0.26	0.45	.57	1.29 (0.53–3.13)
MEDHHINC					**−0.00**	**0.00**	**.02**	**0.99 (0.99–0.99)**
WALK_DSTY					**0.00**	**0.00**	**.00**	**1.00 (1.00–1.00)**
Intercept	**2.85**	**0.40**	**.00**	**17.32 (7.85–38.18)**	**2.99**	**0.42**	**.00**	**19.84 (8.63–45.6)**

NOTE: Coefficients in bold are significant at $p \leq .05$. Coeff. = coefficient and CI = confidence interval. Home model: *n*, 2,729; null deviance: −2L[0], 3,314.0 (degrees of freedom = 2,728); residual deviance: −2L[B], 2,569.8 (degrees of freedom = 2,714); −2(L[0] − L[B]), 744.2 (p <.001); McFadden ρ^2, 0.225 (0.220 adjusted). School model: *n*, 2,729; null deviance: −2L[0], 3,314.0 (degrees of freedom = 2,728); residual deviance: −2L[B], 2,590.3 (degrees of freedom = 2,715); −2(L[0] − L[B]), 723.7 (p <.001); McFadden ρ^2, 0.218 (0.214 adjusted).

TABLE 5 Binomial Logistic Regression for Walking: School-to-Home Trips

	Home Model				School Model			
Variable	Coeff.	Standard Error	*p*-Value	Odds Ratio for Walking (95% CI)	Coeff.	Standard Error	*p*-Value	Odds Ratio for Walking (95% CI)
AGE (ref.: 11 year)								
12 year	**0.36**	**0.12**	**.003**	**1.44 (1.13–1.83)**	**0.36**	**0.12**	**.003**	**1.44 (1.13–1.83)**
13 year	**0.32**	**0.12**	**.009**	**1.38 (1.08–1.76)**	**0.31**	**0.12**	**.01**	**1.36 (1.07–1.73)**
CHILD	–0.11	0.01	.09	0.90 (0.80–1.01)	–0.10	0.06	.15	0.91 (0.80–1.02)
VEH_LIC	**–0.94**	**0.13**	**.00**	**0.39 (0.30–0.50)**	**–1.03**	**0.12**	**.000**	**0.36 (0.28–0.45)**
DISTANCE	**–1.26**	**0.07**	**.00**	**0.28 (0.25–0.32)**	**–1.27**	**0.07**	**.000**	**0.28 (0.25–0.32)**
Built Environment at Residence								
LOCAL	–0.02	0.02	.21	0.99 (0.94–1.01)				
BLOCK	0.04	0.02	.053	1.04 (0.99–1.09)				
DIST_CBD	0.00	0.00	.20	1.00 (0.99–1.00)				
BLOCK*DIST_CBD	**–0.00**	**0.00**	**.02**	**0.99 (0.99–0.99)**				
RET_BAL (ref.: <.1)								
>0.1	0.23	0.32	.45	1.27 (0.68–2.37)				
JOB_BAL (ref.: <0.5)								
0.5<job/pop<1.5	**–0.79**	**0.35**	**.02**	**0.46 (0.23–0.90)**				
>1.5	–0.02	0.64	.98	0.98 (0.28–3.45)				
MEDHHINC	**–0.00**	**0.00**	**.00**	**0.99 (0.99–0.99)**				
WALK_DSTY	**0.00**	**0.00**	**.03**	**1.00 (1.00–1.00)**				
Built Environment at School								
BLOCK					–0.01	0.02	.75	1.01 (0.97–1.05)
DIST_CBD					0.00	0.00	.69	1.00 (0.99–1.00)
BLOCK*DIST_CBD					–0.00	0.00	.31	0.99 (0.99–1.00)
RET_BAL (ref.: <.1)								
>0.1					–0.36	0.29	.21	0.70 (0.40–1.27)
JOB_BAL (ref.: <0.5)								
0.5<job/pop<1.5					–0.14	0.30	.64	0.87 (0.49–1.55)
>1.5					0.61	0.59	.31	1.84 (0.57–5.88)
MEDHHINC					**–0.00**	**0.00**	**.007**	**0.99 (0.99–0.99)**
WALK_DSTY					**0.00**	**0.00**	**.00**	**1.00 (1.00–1.00)**
Intercept	**2.87**	**0.41**	**.00**	**17.64 (7.95–39.17)**	**3.01**	**0.43**	**.00**	**20.18 (8.71–46.73)**

NOTE: Coefficients in bold are significant at $p \leq .05$. Home model: *n*, 2,712; null deviance: –2L[0], 3,308.9 (degrees of freedom = 2,711); residual deviance: –2L[B], 2,548.0 (degrees of freedom = 2,697); –2(L[0] – L[B]), 760.9 ($p < .001$); McFadden ρ^2, 0.230 (0.226 adjusted). School model: *n*, 2,712; null deviance: –2L[0], 3,308.9 (degrees of freedom = 2,711); residual deviance: –2L[B], 2,578.0 (degrees of freedom = 2,698); –2(L[0] – L[B]), 730.9 ($p < .001$); McFadden ρ^2, 0.221 (0.217 adjusted).

variables and distance to school (not reported) improved the overall model fit. The results indicated some association between the built environment around both home and school and a child's likelihood of walking to and from school; the built environment near the location of residence was more strongly correlated with mode choice than the built environment around the school. The association between the built environment and mode choice also appeared to be stronger for morning trips; fewer built environment variables were associated with walking in the afternoon period.

As expected, the distance between the residence and school location emerged as the most important factor to explain walking as a mode choice for school transportation; a 1-km (0.62-mi) decrease in travel distance increased the odds of walking by 0.71 to 0.72 times (Tables 4 and 5). This observation is particularly important given that since 1999, more than 200 schools were closed in the province of Ontario, Canada (*37*). In the city of Toronto, 16 public schools were affected by this provincewide restructuring policy, and there is strong indication that additional neighborhood schools will be closed in the near term (*37*). In the United States, a similar trend has been observed during the past decades (*19*). Fewer in number, elementary schools now draw students from larger areas, reducing the proximity between a child's home and school location and likely discouraging walking. The potential impact of the economic rationalization of the school system on mode choice and children's physical activity levels should be the focus of some debate when governments and school boards contemplate school closures.

Some have argued that the neighborhoods around schools (particularly new schools) should be planned with connected streets and an adequate supply of local roads (*19*). The data from this study suggest that some caution should be exercised before the wholesale widespread adoption of such planning and engineering practices. The model results indicated that beyond proximity, the independent effects of other built environment variables—those related to street connectivity—on mode choice were at best moderate. Density of local street intersections was uncorrelated with the choice of walking among children, whereas higher block density (i.e., smaller blocks) around a child's residence appeared to encourage walking only for trips to school in the morning.

At least two previous studies reported a correlation between land use mix around the school location and walking among children (*13, 18*). Findings from this research indicated that sales- and service-related land use near the home or around the school location was not associated with mode choice for school transportation. Children living in TAZs that were overwhelmed by manufacturing, trade, office, and professional employment (i.e., an employment-to-population ratio > 1.5) did not have significantly different mode choice behavior than those living in TAZs with minimum employment-related land use (i.e., an employment-to-population ratio < 0.5). But a moderate balance between manufacturing, trade, office, and professional employment and residential population (i.e., an employment-to-population ratio between 0.5 to 1.5) in the TAZ of a child's residence reduced the likelihood of walking for both morning and afternoon period school trips; having these types of jobs concentrated about the school had a negative association with walking for home-to-school trips.

These findings begin to emphasize the potential differential effects of land use type on children's mobility, particularly for school transportation. It appears that manufacturing, trade, office, and professional employment-related land uses may have a more pronounced effect on a child's travel mode than retail- or service-related land uses. The observed negative association between land use mix and walking is not surprising either, and it perhaps indicates that, unlike the case for adults, for whom land use mix may improve access and pedestrian comfort, a child's mode choice for school trips is determined by concerns about traffic and a child's personal safety near employment locations. Future empirical research will need to consider the design, intensity, or quality of the land use mix (e.g., street orientation, access, building height, type of employment). This additional work may provide a more conclusive explanation for the observed relationship between the presence and composition of such land uses in the neighborhood and the mode choice for school commuting.

As expected, the regression results showed that a child was more likely to walk to or from school in places where other people walked (i.e., the rate of walking per square kilometer area was higher than elsewhere in the study area). Walking was also found to be more common among children living in low-income areas (i.e., in DAs with low median household income) and among those children attending schools located in such areas. The result was indicative only of a potential negative association between DA-level socioeconomic composition and walking to and from school but does not necessarily imply that walking was less common among children from high-income households. McDonald (*38*) reported similar results based on an analysis of the 2001 U.S. National Household Travel Survey; children and youth living in disadvantaged neighborhoods were more likely to walk to school. The potential causal relationship between neighborhood socioeconomic status and walking among children, however, remains an area to be explored through further research.

The model results also demonstrated a negative association between the variable for block density–distance-to-CBD interaction and walking. This finding suggests that a child living in a neighborhood with smaller blocks and located far from the CBD would be less likely to walk than someone living in a place with larger blocks but located closer to the CBD. Although the marginal effect on mode choice of this interaction between urban design and location is relatively small (odds ratio = 0.99), the result suggests, for example, that suburban places in the study area that either possess neotraditional design elements or, alternatively, were developed at a time when the so-called neotraditional elements were *de rigueur* (e.g., during the 19th century) may not produce walking school trips at a rate comparable with the study area's inner-urban neighborhoods.

An important result indicated that the built environment at the home end of the school trips has a stronger correlation with mode choice, which implies that built environment interventions at the school end could be less successful in encouraging walking compared with interventions closer to home. For example, in Canada, the School Travel Planning project, a community-based initiative funded by the Public Health Agency of Canada, advocates built environment interventions primarily at the school end to promote active commuting to school (*39*). On the basis of the model results, it appears that public capital and tax revenues could perhaps be better spent by improving infrastructure more equitably across a neighborhood instead of focusing capital improvement on the school end alone.

Other than the built environment, sociodemographic characteristics that describe the household and the child explained some of the variation in mode choice. A child's sex was not associated with mode choice, but older children tend to walk more than younger children for both directions of the school trip. Although other studies have also reported a correlation between age and school travel (*15, 16*), this research found that age-related effects on mode choice were particularly strong in the afternoon compared with the morning period trips (Tables 4 and 5). With regard to automobile access, as expected, the odds of being driven to and from school increased with the ratio of vehicles to licensed householders. The question remains whether this household "automobility" is merely a manifestation of affluence in the context of mobility or reflects some broader association between the culture of auto-centeredness of a household's daily activity and travel practices and the mode used for school travel.

There remain three broad issues requiring further consideration: self-selection, the trip-based approach of this and other studies, and geographical transferability. First, households become periodically involved in longer-term decisions such as residential location choice. The decision about where to live enables a household with sufficient income to select itself into a walkable or drivable neighborhood. This self-selection may in turn facilitate or discourage active school travel. Although this research conceptualized the potential causal relationship between built environment variables and walking, it could not, largely because of data limitations, control for self-selection bias.

Second, this study, and most of the school transport literature, adopted a trip-based approach; the school trip is studied in isolation, extracted from broader patterns of daily activities and travel. Although there are exceptions to this trend (*24,40*), and although the trip-based approach holds value because of how it relates to school travel planning practices (e.g., SR2S in the United States, Active and Safe Routes to School in Canada), mode choice for school transportation can conceivably be influenced by a household's broader activity–travel interactions. For example, the decision to escort a child to or from school (and perhaps the use of an automobile for the trip) may depend on the availability of parents or adult caregivers. This availability problem, one that may reflect the temporal asymmetry that typically exists between the school day and the work day, may be an important aspect of the mode choice process in addition to built environment influences.

This availability hypothesis is implicitly reflected in the current estimation results indicating that the built environment does not have a uniform association with mode choice across the morning and afternoon periods. Adults who remain at work in the afternoon, for example, are potentially unavailable for the school trip to home, which may contribute to temporal differences in mode choice. Being a trip-based survey, the TTS does not provide direct observation on caregiver time constraints; the potential influence of such activity–travel constraints on mode choice could not be examined in this research. Broader behavioral insights could emerge through a more regular nesting of children's mobility within the activity–travel paradigm, which remains the subject of future work.

Last, the geographical transferability of these findings to other places in North America requires some careful thought, particularly given that more than twice as many children in the current sample walked to or from school than were driven. This finding contrasts with those from several U.S. studies, in which the automobile emerged as the dominant travel mode (*13, 15, 19*). The Toronto case is more similar to that of the United Kingdom, where, in 2006, 41% of 11- to 16-year-olds walked to school and 20% were driven (*41*). Furthermore, in this study, the ratio of children walking and being driven was found to be similar between the morning and afternoon periods, which is also atypical of the broader North American context (*17–19*). This comparative statement could be a sampling effect, given that previous research by the authors, which studied all TTS school trips, indicated a 5% increase in walking for 11- to 13-year-olds for afternoon period school-to-home trips (*17*). Either way, walking emerges as the dominant travel mode for school trips in the study area. Transnational and intercity differences in school travel mode share further validate the need for the development of a local empirically constructed knowledge base about the school travel behavior of children and youth.

CONCLUSION

This research explored the effect of the built environment on children's travel mode choice for journeys to and from school. The main findings indicate that (*a*) the built environment explains some variation in children's mode choice; (*b*) other than distance between home and school, the association between individual built environment variables and walking or driving is only moderate; (*c*) the built environment around the residence is a stronger correlate of mode choice than the built environment around school; and (*d*) the effect of the built environment on mode choice is subtly weaker for afternoon (school-to-home) trips than for morning (home-to-school) trips. Also, findings from this research suggest that differences may exist between children and adults in terms of how the built environment affects mode choice. This study begins to address this research challenge by taking a child-centered approach to understanding the relationship between the built environment and school travel. There is potentially much to be gained by refining this approach to extend the knowledge base on school transportation, childhood mobility, and physical activity. Urban planners and community-based organizations who are interested in improving the built environment to encourage active mobility (e.g., walking, cycling) among children and youth should also systematically address these differences when interventions are designed.

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