Safety and School Travel

How Does the Environment Along the Route Relate to Safety and Mode Choice?

Kristian Larsen, Ron N. Buliung, and Guy E. J. Faulkner

This study examines the relationship between safety, the built environment, and the mode of travel to and from school. The paper contributes to the literature by analyzing the actual route traveled through the use of objective traffic data within school neighborhoods. Parents and children completed a survey and mapping exercise to obtain travel routes to and from school, a methodological improvement over network shortest-path analysis. Manual traffic counts around the sampled schools ($n = 17$) were conducted. Logistic regression analysis confirmed a priori expectations about the effects of distance, gender, and the number of vehicles per licensed driver. New insights into safety were produced through inclusion of objective metrics designed to explore the safety of the pedestrian environment. A higher number of vehicles, a higher number of crossing streets, incomplete sidewalk networks, and the presence of parking facilities emerged as potentially important transport supply-, design-, and safety-related factors. If children perceived their neighborhood to be a safe area in which to walk alone, they were also more likely to walk. For parents, the perception that strangers were present and the presence of busy streets influenced the mode of travel. Different effects were produced across separately estimated home-to-school and school-to-home models.

Over the past four decades, decreasing rates of active travel to school have been accompanied by an increasing prevalence of childhood obesity (*1–4*). The recent decline in physical activity may influence the increasing prevalence of childhood obesity (*5*). Travel between home and school presents a potential opportunity to establish daily physical activity through active transport to school (ATS) (*6*). Walking to school alone does not allow children to meet their daily physical activity needs or meet national guidelines, but it can be one part of a daily activity bundle necessary to produce an active, healthy lifestyle.

The distance between home and school is often reported in the literature to be the most common correlate of school travel mode choice (*7–11*): as the distance increases, the odds of walking decrease. Distance is important, but other aspects, such as convenience and safety, influence rates of ATS. Even for short distances, recent studies have found that parents may drive their children to school, as it is perceived to be more convenient (*7, 12, 13*). Convenience partially relates to parental perception about the time necessary to overcome travel distance.

Concerns about child safety are another reason why parents drive children to and from school (*8, 14, 15*). The concept of child safety is twofold; it consists of both personal security, that is, social fears or threats to the body or mind perpetrated by others, such as strangers or bullies, and safety from traffic. Personal security can involve both objective and perceived risks. Common concerns for parents are the risk of abduction, interaction with strangers, or fear of crime (*12, 16*). Children, however, are concerned about strangers but may have additional sources of fear, such as bullies, stray animals, or older kids (*14, 16*). Objective and perceived measures of vehicle speed, traffic volume, fleet characteristics, sidewalks, and street crossings are potentially key traffic safety issues (*17, 18*).

Street crossings, by type, and the distribution of intersections may also affect mode choice, but research to date has produced mixed results. For example, higher intersection density may associate with walking (*19–21*) or may not associate with walking at all (*22, 23*). The type of street crossing could also be an important factor, as major intersections may be more difficult to cross than local streets. One study reported that many children are driven to school because of dangerous road crossings (*15*), although Schlossberg et al. found no connection between the presence of major street crossings and mode choice (*19*). Railway crossings may also affect mode choice, but little supportive evidence exists (*19, 24*).

The presence of a complete sidewalk network affects risk perception and has been positively associated with higher rates of ATS in some studies (*18, 25*) but not at all in others (*8, 24*). Neighborhoods may vary widely according to the characteristics that may support or hinder ATS. Such differences may intensify along class divides. For example, higher-income households commonly report lower ATS rates than lower-income households (*20, 24, 25*). Although ATS rates are often higher for lower-income respondents, the risk of pedestrian injury has also been shown to be higher in lower-income neighborhoods; income effects are therefore not limited to mode choice but extend to safety as well (*26*).

Despite much discussion about safety in the ATS literature and public policy domains, few studies have examined how observed traffic counts and vehicle fleet characteristics associate with school travel mode choice (*8, 14, 19*). The pedestrian safety literature has found a link between higher traffic volumes and injury risk (*27, 28*). The existence of such a link suggests that traffic volume may relate to safety and mode choice. Fleet characteristics (type, size) may also influence adult and child perceptions of safety risk. From an objective point of view and from the perspective of the risk of injury, larger vehicles put pedestrians at a greater risk for more severe injury and death (*29*).

K. Larsen, Department of Geography and Planning, University of Toronto, 100 Saint George Street, Toronto, Ontario M5S 3G3, Canada. R. N. Buliung, Department of Geography, University of Toronto, Mississauga, 3359 Mississauga Road North, Mississauga, Ontario L5L 1C6, Canada. G. E. J. Faulkner, Faculty of Kinesiology and Physical Education, University of Toronto, 55 Harbord Street, Toronto, Ontario M5S 2W6, Canada. Corresponding author: K. Larsen, kristian.larsen@utoronto.ca.

Transportation Research Record: Journal of the Transportation Research Board, No. 2327, Transportation Research Board of the National Academies, Washington, D.C., 2013, pp. 9–18.
DOI: 10.3141/2327-02

METHODS

Study Area and Data

The study described here was set in the city of Toronto, Ontario, Canada, which has a population of approximately 2.5 million people. Toronto represents an ideal study area, as its neighborhoods present contrasting transportation options, land uses, built environments, and social characteristics. Although city form can be classified in many ways, this study makes use of two broad categories that reflect the historical and political context of Toronto's growth since the late 1800s. The central city consists of many older neighborhoods surrounding the downtown core, and the inner suburbs include more recently constructed neighborhoods politically amalgamated in 1998.

As part of the larger Built Environment and Active Transport project, students in Grades 5 and 6 (n = 1,035) at 17 elementary schools completed activity–travel behavior surveys and mapping exercises. Student selection began in January 2010, when all elementary school principals within the Toronto District School Board (n = 469) received an invitation to participate in the project. From the pool of interested principals, selective sampling took place to ensure representation by income and built environment. Nine of the sampled schools were within the central city, and eight were in the inner suburbs. A dummy variable broadly examined the effects of location (central city and inner suburbs).

The University of Toronto research ethics board and the Toronto District School Board ethics review board granted ethics approval in advance. Individual schools, parents, and students gave consent to participate before data collection. Data collection took place in the spring and fall of 2010 and 2011. Grades 5 and 6 teachers recruited children and parents. Eligible students obtained a consent form asking for the child's home address. Home addresses and school locations were used to produce color maps (aerial photographs) of participant neighborhoods on ledger-size paper (279 × 432 mm).

After in-classroom instruction, children brought home a parental survey and a map on which they could draw (with parental supervision) their typical route to and from school. The child and parent surveys allowed researchers to examine how perceived characteristics of the neighborhood and safety relate to mode choice. All questions about safety and environmental perceptions were entered into a preliminary univariate analysis to test for associations with mode choice (Table 1).

TABLE 1 Significance of Correlations in Preliminary Analysis

	To School				From School			
	Child		Parent		Child		Parent	
Variable	p-Value	+/–	p-Value	+/–	p-Value	+/–	p-Value	+/–
Age	.055	na	.199	–	.152	–	.969	–
Gender (girls as referent)	**<.001**	+	**<.001**	+	**<.001**	+	**<.001**	+
Gender of parent (mother as referent)	na	na	.151	+	na	na	.311	+
Distance	**<.001**	–	**<.001**	–	**<.001**	–	**<.001**	–
Intersections	**<.001**	–	**<.001**	–	**<.001**	–	**<.001**	–
Major crossings	**<.001**	–	**<.001**	–	**<.001**	–	**<.001**	–
Railway crossings	.467	–	.419	–	.052	–	.085	–
Proportion missing sidewalks	**<.001**	–	**<.001**	–	.13	–	.142	–
Maximum traffic	**<.001**	–	**<.001**	–	**<.001**	–	**<.001**	–
Land use mix	**<.004**	+	**<.004**	+	.124	–	.124	–
Traffic-calming feature density	**<.001**	–	**<.001**	–	**<.001**	–	**<.001**	–
Traffic density	.091	–	**.016**	–	**.003**	–	**.002**	–
Vehicle fleet index	**.001**	+	**.004**	+	.132	–	.076	–
Unweighted vehicle mix	.095	+	.295	+	.053	+	.282	+
Home DA income	**<.001**	–	**<.001**	–	**<.001**	–	**.003**	–
Street tree density	.056	+	**.003**	+	.984	–	.597	+
Parking facilities	**<.001**	–	**<.001**	–	**<.001**	–	**<.001**	–
Vehicles per licensed driver	na	na	**<.001**	–	na	na	**.027**	–
Neighborhood: inner suburbs	**<.001**	–	**<.001**	–	**<.001**	–	**<.001**	–
Education, father								
Secondary	na	na	.408	+	na	na	.876	+
College	na	na	.837	–	na	na	.447	–
University	na	na	.660	+	na	na	.970	+
Graduate	na	na	.970	–	na	na	.668	–
Education, mother								
Secondary	na	na	**.026**	+	na	na	**.998**	+
College	na	na	.123	–	na	na	.939	–
University	na	na	**.037**	+	na	na	**.253**	+
Graduate	na	na	**.034**	+	na	na	**.515**	+

(continued)

TABLE 1 *(continued)* **Significance of Correlations in Preliminary Analysis**

	To School				From School			
	Child		Parent		Child		Parent	
Variable	*p*-Value	+/–	*p*-Value	+/–	*p*-Value	+/–	*p*-Value	+/–
Not enough sidewalks								
Strongly agree	na	na	**.001**	–	na	na	**.058**	–
Agree	na	na	**<.001**	–	na	na	**.001**	–
Neither	na	na	**.009**	–	na	na	**<.001**	–
Disagree	na	na	.172	–	na	na	.086	–
Enough crosswalks								
Strongly agree	na	na	.063	–	na	na	.653	–
Agree	na	na	**<.001**	–	na	na	**.015**	–
Neither	na	na	.343	–	na	na	.860	–
Disagree	na	na	**.002**	–	na	na	**.049**	–
Fear of strangers								
Strongly agree	na	na	**<.001**	–	na	na	**<.001**	–
Agree	na	na	**<.001**	–	na	na	**.003**	–
Neither	na	na	**.001**	–	na	na	**.036**	–
Disagree	na	na	.054	–	na	na	.201	–
Traffic around school								
Strongly agree	na	na	**<.001**	–	na	na	**<.001**	–
Agree	na	na	**<.001**	–	na	na	**<.001**	–
Neither	na	na	**.012**	–	na	na	**.001**	–
Disagree	na	na	**.027**	–	na	na	.117	–
Crosses busy streets								
Strongly agree	na	na	**<.001**	–	na	na	**<.001**	–
Agree	na	na	**<.001**	–	na	na	**<.001**	–
Neither	na	na	**<.001**	–	na	na	**<.001**	–
Disagree	na	na	**.009**	–	na	na	**.009**	–
Drivers are too fast								
Strongly agree	na	na	**<.001**	–	na	na	**<.001**	–
Agree	na	na	**.023**	–	na	na	**.023**	–
Neither	na	na	**.002**	–	na	na	**.004**	–
Disagree	na	na	.241	–	na	na	.568	+
Crossing guards								
Strongly agree	na	na	**.037**	–	na	na	**.078**	–
Agree	na	na	**.005**	–	na	na	**.018**	–
Neither	na	na	.171	–	na	na	.216	–
Disagree	na	na	**.038**	–	na	na	**.055**	–
Live in a safe area								
Strongly agree	na	na	.926	+	na	na	.794	+
Agree	na	na	.138	–	na	na	.314	–
Neither	na	na	.344	–	na	na	.355	–
Disagree	na	na	.184	–	na	na	.037	–
Safe area to walk								
Do not know	**.05**	+	na	na	**.019**	+	na	na
Yes	**<.001**	+	na	na	**<.001**	+	na	na
Safe crossing roads								
Do not know	.353	+	na	na	.515	+	na	na
Yes	.136	+	na	na	.006	+	na	na
Lots of traffic								
Do not know	.236	+	na	na	.294	+	na	na
Yes	.397	–	na	na	.402	–	na	na
Fast cars								
Do not know	.611	+	na	na	.839	–	na	na
Yes	.913	–	na	na	.159	–	na	na
Fear of strangers								
Do not know	.594	–	na	na	.175	–	na	na
Yes	.466	–	na	na	.184	–	na	na
Fear of older kids								
Do not know	.451	+	na	na	.956	–	na	na
Yes	.118	+	na	na	.268	+	na	na

NOTE: Significant variables with a *p*-value of <.05 are in bold; + = positive association; – = negative association; na = not applicable; DA = dissemination area.

Heads-up digitizing generated geographic information system-based separate routes to and from school. Data loss resulted from incomplete or illegible maps. The final data set included 978 routes to school and 981 routes from school. The digitized routes allowed exploration of objective environmental characteristics along each child's reported route. Most studies examining school travel use aggregated data for either the home or the school neighborhood (*8, 9, 20, 21*), and a few recent studies have examined characteristics along the shortest path between home and school (*19, 24*). Use of a drawn route as the unit of analysis is a methodological improvement over previous work and produces a more accurate representation of the environment (*30*).

The City of Toronto provided data on sidewalks, railways, street trees, traffic-calming device location, and the street network. These data were used to construct route-based environmental variables. Parcel-level land use data from the Municipal Property Assessment Corporation were also used to generate land use metrics. Researchers verified all of the data sets along the routes in this study with the assistance of aerial photography and field visits, when required.

Built Environment

This section explains the approaches used to model concepts of the built environment. Several measures of transport supply and the density of route features were estimated (i.e., the number of features per route kilometer). These included crossed intersections, active railway crossings, major street crossings (major streets were classified by the City of Toronto), traffic-calming devices, and street trees. Few studies examine how traffic-calming features influence school travel. Traffic-calming devices in this study included chicanes, speed bumps, raised intersections, gateways, raised crosswalks, and traffic circles. Street trees may encourage walking for the trip to school (*9*). Calculation of the number of street trees along each route was based on the distance traveled, and this calculation produced a variable for route street tree density.

Sidewalk availability is assumed to be necessary for the facilitation of ATS. Sidewalk coverage was measured as the proportion of a route with missing sidewalks. Sidewalks were considered to be missing only if they were not present on either side of the street.

Land use mix is often measured by use of an entropy index based on the area of land dedicated to particular land uses (*9, 24*). This study examined the actual route traveled and not the area surrounding the home or school. Thus, a new route-based approach examined the mix of land uses along the property frontages for each child's route. This method uses the same approach as previous work but uses it at a different spatial scale because of the route-based nature of this study. All land parcel polygons within the city of Toronto were classified into five land use classes (parks, residential, institutional, industrial, and commercial). Land use parcels were then transformed into linear features at the front of each property. The total length of frontage for each land use was compiled for every route, and an entropy approach was used to represent land use mix (LUM) by use of the follow formula:

$$\text{LUM} = -\frac{\sum lu[pu \ln(pu)]}{\ln(n)}$$

where

lu = land use classification integer,
pu = proportion of parcel frontage within a land use category, and
n = total number of land use classes.

The values ranged from 0 to 1, where 0 represents a route populated by a single land use and 1 indicates the presence and equal distribution of all five land uses.

Many participants did not provide individual-level data on income when completing the survey but did report their level of educational attainment. Preliminary analysis included the individual educational attainment variable along with a measure of the median household income at a scale smaller than the neighborhood (i.e., the Canada census dissemination area [DA]).

Traffic Environment

Qualitative research examining traffic and school travel has reported a relationship between the number of vehicles around the school and safety (*17*). School travel interventions often focus on the traffic environment at the school end. Manual traffic counts were taken at all access and egress points around each sampled school. These counts produced a destination-focused analysis of the role of traffic on mode choice. This approach to data collection ensures that traffic data are available for at least one intersection for every child. Traffic counts were conducted in the morning and afternoon. Data were collected by methods used by Boarnet et al. and commenced one-half hour before school started in the morning and continued for another 15 min after school began (*18*). The same approach was applied for the journey home from school, in which data collection commenced 15 min before the end of the school day. In agreement with common practice, data collection took place only on Tuesdays, Wednesdays, and Thursdays; Mondays and Fridays have atypical traffic patterns (*31*). Traffic data were collected only in the spring and fall and were not collected on days with poor weather. The counters were also instructed to record data on vehicle type, and training was given in advance to help the counters distinguish different vehicles.

This study used the observed traffic data in novel ways. Two measures of the traffic environment were used. The first measure was the traffic volume (observed count) experienced at the school end by examination of the maximum volume that a child faced at those locations where his or her route intersected with a data collection point. This approach takes into consideration findings from the pedestrian safety literature in which a greater volume correlates with perceived safety risk (*27, 28*). This correlation assumes that differences in volume at the high end most likely associate systematically with safety and mode choice. For the second measure, tests also examined traffic density at the school end to understand how average traffic volume influences mode choice.

To date, no known study has examined how fleet characteristics relate to either mode choice or safety. It is unknown exactly how this particular aspect of the traffic environment interacts with safety perceptions or mode choice. Perhaps, for example, a disproportionate presence of larger vehicles could produce differences in perceived safety and mode choice. Passenger car equivalents are a common measure used in the transportation demand and forecasting literature to model the impact of larger vehicles on road systems. No known vehicle index or multiplier for linking vehicle fleet characteristics with pedestrian safety exists. This study involved experimentation with a vehicle weight-based multiplier to create a car equivalent for the pedestrian safety application. The difference between smaller and larger motor vehicles in pedestrian safety relates to vehicle mass and speed. Fleet size plays a role in vehicle-on-vehicle collisions, as a direct inverse relationship between the mass of the vehicle and risk of fatality exists (*32*). The following multipliers were applied: 1.0 for a car, 1.3 for an SUV or minivan, 11.2 for a bus, 6.1 for a school bus, and 13.2 for a truck (*33, 34*). The mass of a bus, school bus, and truck can differ substantially on the basis of the number of occupants or the load. For these types of vehicles, the multiplier uses the average weight between a full and an empty vehicle. The average weight thus implies that a bus or a truck is at half of its capacity.

A weighted vehicle fleet index examines the characteristics of the vehicle fleet around each school. Observed fleet data were aggregated to four vehicle categories: passenger vehicles, transit vehicles, school buses, and trucks. Passenger vehicles included cars, minivans, and SUVs. A reverse entropy index models the vehicle mix around each school:

$$\text{fleet mix} = \left\{ \frac{\sum v\left[pv \ln\left(pv\right)\right]}{\ln\left(n\right)} \right\} + 1$$

where

v = vehicle type,
pv = proportion of vehicle types at each intersection dedicated to a particular category (i.e., passenger vehicle, transit vehicle, school bus, or truck), and
n = total number of categories.

Fleet mix scores ranged from 0 to 1, where 0 is a mix dominated by trucks, transit, and school buses and a score of 1 represents an intersection with only passenger vehicles. To further test for fleet effects, in a preliminary analysis an unweighted vehicle mix index that applied the same approach but without vehicle type multipliers was tested.

Few studies to date have examined whether parking or drop-off facilities at the school relate to mode of travel. It is unknown how this feature associates with mode of travel, but it is likely that these facilities encourage driving because they make it easier. Site visits to each school surveyed parking facilities and drop-off locations. Schools were coded as having parking facilities if pickup and drop-off zone signage was observable or if a school had a drive-through area in front of the school for drop-off and pickup.

Empirical Analysis and Modeling

Univariate logistic regression was first used to determine variables independently associated with walking (Table 1). Factors such as distance and the genders of the child and the parent, along with automobile availability, were analyzed to control for these individual characteristics of the child and adult. Variables continued into subsequent analyses by use of a p-value cutoff of <.05. For categorical responses, three of the four categories had to meet the criterion of a p-value of <.05 and the other category had to approach significance with a p-value of <.1. In an ideal situation, a multinomial analysis would be completed; but the number of cases for bicycling, transit, and school bus ($n = 58$) did not allow such modeling. Only children who were driven in a vehicle or walked to and from school ($n = 905$) were included in the analysis. Although only 22 students rode a school bus, all Toronto District School Board students living more than 1.6 km from school are eligible to take the school bus. The Toronto District School Board measures the distance along the shortest public thoroughfare from the child's residence to the closest school access point.

Multicollinearity analysis of the filtered set of variables followed the unadjusted modeling exercise, and Pearson correlations and variance inflation factor approaches were used. These tests discovered multicollinearity for the traffic maximum and density variables along with the weighted and unweighted vehicle fleet mix. Because preliminary testing revealed greater significance for the maximum traffic and weighted vehicle fleet index variables, these variables remained in the adjusted models.

Model Specification and Structure

Binomial logistic regression modeling examines how characteristics of the traffic environment relate to mode of travel with walking as the dependent variable. The purpose of these models is to help explain how perceived and objective measures of traffic and safety associate with mode choice. Recent studies have shown different patterns in the trip to school versus the trip from school (*10, 24*), so separate models were estimated for trips to and from school.

RESULTS

Descriptive statistics for the cases included ($n = 905$) are reported in Table 2. Nearly 68% of the children ($n = 654$) walked to school and 26% were driven ($n = 251$). Although not included in the analysis, only 22 children (2%) rode the school bus, 19 cycled (2%), and 17 took transit (2%) to school. For the trip home, rates varied slightly, with 76% of children walking ($n = 733$) and 18% being driven ($n = 173$). Alternative modes remained stable, with 2% of the children in the sample biking, taking transit, or riding a school bus home from school.

The average age of the sampled children was 10.5 years. Fifty-four percent of the respondents were girls ($n = 482$) and 46% were boys ($n = 516$). A total of 456 respondents lived in the central city (50%) and 448 (50%) lived in the inner suburbs; 436 (49%) students were from high-income neighborhoods, and 468 (51%) were from lower-income areas. Nearly 60% of the sample had access to parking facilities at the school ($n = 533$). More than 50% of the fathers and 46% of the mothers had a university degree.

The median distance for each of the trips to and from school was 634 m, and the mean distance varied slightly (895 to 900 m). Any difference in trip length to and from school relates to the different routes taken for these trips. Most respondents had to cross five streets, but few of these streets were classified as major roads. Traffic-calming features were present for some of the routes, but many routes did not include these devices ($n = 638$). The values for land use mix were quite low. The low value means that single land uses dominated the landscape for most routes. The traffic environment was different during the trips to and from school. More vehicles were around schools in the a.m. period, and most of these vehicles were passenger vehicles. This likely relates to the higher rates of driving during the trip to school, as rates of driving are higher for the trip to school, and most children are in passenger vehicles.

REGRESSION MODELS

As expected, distance emerged as one of the strongest correlates of school travel mode choice (Table 3). As distance increased, the odds that a child would walk decreased. Child gender was also a significant

TABLE 2 Descriptive Statistics for Participants' Routes

	To School			From School		
Variable	Mean	Median	SD	Mean	Median	SD
No. of vehicles per licensed driver	0.85	1.00	0.28	0.85	1.00	0.28
Distance to school (m)	900.21	634.10	1,329.37	895.35	634.28	1,276.30
No. of intersections crossed on route	5.85	5.98	3.16	5.73	5.83	3.16
No. of major street crossings on route	1.69	0.00	2.58	1.57	0.00	2.41
Maximum traffic (no. of vehicles) on route	470.89	281.00	510.40	407.60	229.00	468.02
Vehicle fleet index	0.44	0.42	0.19	0.35	0.34	0.25
No. of missing sidewalks	0.03	0.00	0.11	0.03	0.00	0.10
Street tree density	74.48	70.30	64.82	82.60	78.07	60.04
Income ($)	72,495.98	70,290.00	40,564.06	72,495.98	70,290.00	40,564.06
Traffic-calming feature density	0.55	0.00	1.34	0.63	0.00	1.53
Land use mix	0.24	0.18	0.24	0.23	0.18	0.24

NOTE: Data are for 905 cases. SD = standard deviation; no. = number.

TABLE 3 Logistic Regression Estimation Results with Walk as Dependent Variable

						95% CI	
Variable	Coefficient	SE	Wald	*p*-Value	Odds Ratio	Lower	Upper
To School							
Gender[a]	**0.530**	**0.208**	**6.469**	**.011**	**1.698**	**1.129**	**2.554**
Vehicles per licensed driver	**−1.316**	**0.408**	**10.400**	**.001**	**0.268**	**0.121**	**0.597**
Neighborhood type: inner suburbs[b]	**−1.501**	**0.356**	**17.744**	**<.001**	**0.223**	**0.111**	**0.448**
Distance to school (km)	**−1.501**	**0.244**	**37.979**	**<.001**	**0.223**	**0.138**	**0.359**
Intersections crossed on route	**−0.170**	**0.041**	**17.512**	**<.001**	**0.843**	**0.779**	**0.913**
Major street crossings on route	−0.007	0.061	0.015	.902	0.993	0.881	1.119
Maximum traffic on route[c]	**−0.057**	**0.025**	**5.200**	**.023**	**0.944**	**0.899**	**0.992**
Vehicle fleet index	0.435	0.748	0.338	.561	1.545	0.356	6.693
Missing sidewalks[d]	**−2.672**	**0.936**	**8.151**	**.004**	**0.069**	**0.011**	**0.433**
Street tree density	−0.001	0.002	0.073	.788	0.999	0.995	1.004
Income[e]	−0.003	0.003	1.579	.209	0.997	0.991	1.002
Land use mix	0.301	0.567	0.282	.595	1.351	0.445	4.105
Parking facilities at the school[f]	**−0.768**	**0.279**	**7.589**	**.006**	**0.464**	**0.269**	**0.801**
Traffic calming density	0.028	0.092	0.090	.764	1.028	0.858	1.231
Safe area to walk alone[g]							
Do not know	0.386	0.392	0.973	.324	1.472	0.683	3.172
Yes	**0.837**	**0.370**	**5.118**	**.024**	**2.310**	**1.118**	**4.770**
Fear of strangers[h]							
Strongly agree	**−0.877**	**0.441**	**3.951**	**.047**	**0.416**	**0.175**	**0.988**
Somewhat agree	**−0.902**	**0.434**	**4.328**	**.037**	**0.406**	**0.173**	**0.949**
Neither agree nor disagree	−0.810	0.480	2.851	.091	0.445	0.174	1.139
Somewhat disagree	−0.844	0.483	3.051	.081	0.430	0.167	1.109
Heavy traffic around the school[h]							
Strongly agree	−0.414	0.393	1.105	.293	0.661	0.306	1.430
Somewhat agree	−0.734	0.378	3.766	.052	0.480	0.229	1.007
Neither agree nor disagree	−0.537	0.461	1.351	.245	0.585	0.237	1.445
Somewhat disagree	−0.668	0.422	2.504	.114	0.513	0.224	1.173
Busy streets to cross[h]							
Strongly agree	**−1.385**	**0.430**	**10.382**	**.001**	**0.250**	**0.108**	**0.581**
Somewhat agree	−0.046	0.358	0.017	.897	0.955	0.473	1.926
Neither agree nor disagree	−0.265	0.355	0.560	.454	0.767	0.383	1.537
Somewhat disagree	0.060	0.276	0.048	.827	1.062	0.618	1.825
Constant	6.854	.961	50.912	<.001	947.486		

(continued)

TABLE 3 *(continued)* **Logistic Regression Estimation Results with Walk as Dependent Variable**

Variable	Coefficient	SE	Wald	*p*-Value	Odds Ratio	95% CI Lower	95% CI Upper
From School							
Gender[a]	**0.710**	**0.240**	**8.778**	**.003**	**2.034**	**1.272**	**3.254**
Vehicles per licensed driver	−0.470	0.435	1.167	.280	0.625	0.267	1.466
Neighborhood type: inner suburbs[b]	**−0.974**	**0.347**	**7.869**	**.005**	**0.378**	**0.191**	**0.746**
Distance to school (km)	**−1.270**	**0.219**	**33.684**	**<.001**	**0.281**	**0.183**	**0.431**
Intersections crossed on route	**−0.171**	**0.045**	**14.188**	**<.001**	**0.843**	**0.772**	**0.921**
Major street crossings on route	0.059	0.070	0.713	.398	1.061	0.925	1.217
Maximum traffic on route[c]	−0.010	0.025	0.150	.698	0.990	0.944	1.039
Income[e]	**−0.008**	**0.003**	**7.689**	**.006**	**0.992**	**0.987**	**0.998**
Land use mix	−0.973	0.633	2.364	.124	0.378	0.109	1.306
Parking facilities at the school[f]	−0.228	0.308	0.546	.460	0.796	0.435	1.457
Safe area to walk alone[g]							
Do not know	0.383	0.377	1.034	.309	1.467	0.701	3.071
Yes	**1.184**	**.365**	**10.492**	**.001**	**3.266**	**1.596**	**6.685**
Fear of strangers[h]							
Strongly agree	**−1.217**	**0.545**	**4.985**	**.026**	**0.296**	**0.102**	**0.862**
Somewhat agree	−0.856	0.537	2.543	.111	0.425	0.148	1.217
Neither agree nor disagree	−0.390	0.603	0.418	.518	0.677	0.208	2.207
Somewhat disagree	−0.769	0.606	1.611	.204	0.464	0.141	1.520
Heavy traffic around the school[h]							
Strongly agree	−0.042	0.476	0.008	.930	0.959	0.377	2.438
Somewhat agree	−0.268	0.444	0.366	.545	0.765	0.321	1.824
Neither agree nor disagree	−0.580	0.473	1.506	.220	0.560	0.222	1.414
Somewhat disagree	−0.124	0.488	0.065	.799	0.883	0.339	2.298
Busy streets to cross[h]							
Strongly agree	**−1.346**	**0.442**	**9.258**	**.002**	**0.260**	**0.109**	**0.619**
Somewhat agree	−0.589	0.383	2.363	.124	0.555	0.262	1.176
Neither agree nor disagree	−0.636	0.396	2.584	.108	0.529	0.244	1.150
Somewhat disagree	−0.278	0.330	0.711	.399	0.757	0.396	1.446
Constant	6.048	.914	43.780	<.001	423.345		

NOTE: Significant variables with a *p*-value of <.05 are in bold. SE = standard error; CI = confidence interval.
[a]Female as referent.
[b]Central city as referent.
[c]Maximum traffic in 100-vehicle increments.
[d]Proportion of route with sidewalk missing on both sides of street.
[e]Home DA level income ($).
[f]No as referent.
[g]No as referent, on the basis of the child survey.
[h]Strongly disagree as referent, on the basis of the parent survey.

factor, as boys were more likely to walk. These results were consistent for both trips. School neighborhoods also played a role, as living in inner suburban areas decreased the likelihood that a child would walk.

For class, the median household income of the home DA was significant only in the model of the trip home from school. Households in DAs described as having a higher income than other places seemed to produce less walking on the trip home. The number of vehicles per licensed driver ratio was significant only for the trip to school and was inversely related to the odds of walking. The number of intersections along the route significantly related to travel mode for both trips, but the need to cross major streets produced no effect. Children faced with routes with many intersections, irrespective of road type, were less likely to walk. The absence of sidewalks was also associated with a decreased odds of walking. Route-based measurement of street trees, traffic-calming features, and land use mix were not statistically associated with the mode choice outcome. It is possible, however, that other approaches to measuring these features in relation to mode choice—or route choice, for that matter—could produce a different result.

For the traffic environment for the trip to school, increased traffic volume at the school end appeared to decrease the odds of walking. Although this may appear to be an expected result, it was significant only for the morning trip. Informed by the preliminary univariate analysis, vehicle fleet index was entered only into the model for the trip to school and was not significant. The finding suggests that for the characteristics at the school end, mode choice may not relate to vehicle fleet mix; the greater concern may be traffic volume overall. Parking facilities were also important only for the trip to school, indicating that the presence of parking facilities may enable driving in some way. Overall, the larger number of significant variables in the model for the trip to school may suggest that the traffic environment around the school has a larger and potentially more diverse set of impacts on mode choice for the trip in the morning than for trips from school at the end of the day.

Attention to the findings for environmental perceptions showed that the odds that children would walk to and from school appeared to be higher for children who perceived that they lived in an area where it is safe to walk alone. Parents' heightened risk perception about strangers appeared to correlate inversely with the odds that their children would walk on both trips. In contrast to findings about the objective measurement of the traffic environment, the perception of heavy traffic around the school was not significant for either trip. Also in contrast to a corresponding objective measure, strong parental agreement on child interaction with too many busy street crossings inversely related to the odds that the children would walk. An interesting finding was the incongruence between objective environmental measurements and the respondent's perception of the same environment.

DISCUSSION OF RESULTS AND CONCLUSION

Traffic, measured according to the maximum volume at intersections where child pedestrian exposure occurs, was a significant factor related to mode choice. This finding is important, as few studies have examined this variable within the context of travel to and from school. Some studies have used aggregated daily counts, but no known study has used traffic counts around the school during the a.m. and p.m. periods. Findings for this variable were not surprising, as a higher traffic volume at an intersection translates to decreases in walking. A higher number of vehicles could produce an unpleasant walking environment. From a safety standpoint, a higher traffic volume could also be associated with an increased risk of pedestrian injury or death. This finding confirms that a link exists between the traffic volume at the school end and ATS.

Although the maximum traffic around the school was significant for the trip to school, it was not for the journey home. This may relate to several differences in the trips themselves. Fewer vehicles were found around the school on the trip home from school. Two reasons for why this may occur exist. The start of the school day begins to overlap the start time of work for many parents, so the morning peak hour coincides with the commencement of school. This coincidence of starting times means that people driving to work will be adding vehicles to the roadway in the morning. Additional vehicles around the school in the morning may also relate to the difference in the rates of driving for the morning and afternoon trips. A nearly 10% increase in the rate of people driving to school over the rate of driving from school was found. The difference between the two trips does not suggest that traffic is not important on the trip home but, rather, that it is more significant in the morning, when traffic volumes are higher. It appears from this finding that traffic and other environmental features are less important on the trip home from school, when more people are walking. This likely relates to parents' work schedules and their inability to pick up their children after school. Although unintended, the lack of synchronicity between school and adult paid work at the end of the day may limit the transport options available to households. This could produce an overall reduction in traffic volumes at the school end and a more temporally fragmented arrival of those parents, who drive their children home or elsewhere at the end of the school day.

Fleet mix around the school did not appear to associate with mode choice. This lack of an association does not mean that fleet mix should be universally ignored with regard to the school travel problem. It could affect route choice, and fleet mix around the home may influence mode of travel. Moreover, and from an injury perspective, vehicle type and size and vehicle speed are of concern. To ensure that methods captured this variable effectively, preliminary analysis tested two measures of the vehicle fleet mix. Because little work on this topic has been performed to date, it was unknown what approach would best capture the conceptualization of vehicle mix. The weight-based index was entered into the regression analysis because it possesses strong conceptual links with the injury problem; it was also a stronger correlate in preliminary analysis. The odds ratio from the vehicle fleet index suggested that in neighborhoods where passenger vehicles dominated the traffic environment, children were more likely to walk, but the finding was not significant. The reasons for the null finding could relate to the dominance of passenger vehicles in the school traffic environment. In general, it seems that a reduction in the number of vehicles may be more important than the vehicle fleet, but more research is necessary.

The availability of a designated place to pick up or drop off children in the morning increased the odds that a child would be driven to school. Few studies have examined this feature, but this study provides some evidence of a link between parking and increased driving. This study examined only designated parking facilities. Staff parking lots or nearby streets may act as unofficial drop-off or pickup zones. The fact that parking matters demonstrates that formal parking facilities do encourage driving. An official drop-off zone may relate to what parents perceive to be the most convenient. From a policy standpoint, it is unlikely that merely removing these designated areas would encourage walking in the short term, as many parents would merely park in nearby areas, but more research on this topic is also needed.

Missing sidewalks negatively influenced rates of walking to school. Many studies have examined how sidewalks associate with ATS, with mixed results being obtained to date (*18, 21, 24*). These mixed findings likely relate to complete sidewalk networks around schools. Although most neighborhoods in Toronto have a complete network, a few areas do not. Findings from the present study suggest that when this feature was missing, the odds of walking decreased. This finding directly translates into policy applications related to sidewalk development; that is, no new development should take place without the construction of a complete sidewalk network. School travel alone probably provides an insufficient business case for sidewalk development, and so the broader benefits of the infrastructure require communication to influential stakeholders.

Several features, such as major street crossings, the presence of traffic-calming features, and land use mix, were not significant factors for mode choice; but they may be associated with the route that children travel. People likely avoid features of the environment that are less pleasing and plan their routes along quiet streets. When the route required children to cross major streets, a higher density of traffic-calming devices and mixed land uses were not related to the mode of travel. This result should not suggest that these features are not important to the environment, nor should it suggest that they are unrelated to school travel. These environmental features did not associate with mode choice for several reasons. The purpose of this paper was to examine mode choice and not route choice. The insignificance of the presence of major street crossings likely relates to the fact that many people did not have to cross busy intersections. As indicated in Table 2, the median number of major streets crossed was 0, suggesting that many routes avoided major intersections.

Children likely intentionally travel along routes on which they do not have to cross many busy streets to make the trip more enjoyable. A similar story likely exists for traffic-calming devices.

Traffic-calming features are supposed to slow vehicles, improve perceptions of safety, and reduce the frequency of collisions for walkers (*35*), although their effectiveness at reducing pedestrian injuries is inconclusive (*36*). These devices are installed on busier streets where it is thought that driver behavior could be modified through design interventions that produce a potentially more benign traffic environment. Little work on school travel has examined this variable, but the null finding may relate to the fact that many children are selecting a route along quieter streets, where speed bumps or other traffic-calming devices are not necessary or where the earlier installation of these devices has produced a desirable walking environment. Similar to the reason why major street crossings were irrelevant, these features influence the routes traveled but not the mode. Future work should examine how children and parents select their routes to and from school to obtain a better understanding of how environmental features influence these decisions.

Characteristics of the social environment were also important. Children living in lower-income households were more likely to walk home from school than those living in high-income households. This finding relates to previous work, as many studies have found that children from higher-income households have lower rates of ATS (*10, 24*). Because this characteristic was significant only for the trip home from school, a connection between income and the parents' work schedules likely exists. Higher-income families may have only one parent working or a parent or parents with flexible work schedules, a household labor scenario that enables more driving. The ability to afford an automobile also typically more readily applies to higher-income households, which generally have higher rates of automobile ownership and use (*37*).

Child and parent perceptions also influenced the mode of travel. Initial analysis revealed that most of the questions from the child and parent surveys pertaining to safety were not significantly associated with school travel (Table 1). Social fears about strangers and older kids, along with perceived traffic, were not statistically significant for children. This may relate to how children answered or understood the survey, or the questions themselves may also not have represented children's concerns. It could also be the case that because the risk perceptions of adults ultimately determine mode choice, the risk perceptions of children did not directly correlate with a mode choice process largely controlled by parents. The only perceived factor from the child respondents that was statistically significant was living in an area where it is safe to walk alone. On the basis of findings from the objective variables, sidewalks, traffic, and intersections may play a role in enhancing children's risk perception; but more work needs to be done to determine the extent to which this is the case. Irrespective of design features, feeling safe was important for children.

Heightened parental perception of child pedestrian risk of injury or death from strangers or busy street crossings appeared to limit the odds that the child would walk. It appears from the presence of contrasting findings on the objective and subjective assessment of environmental risk factors that parents' ideas about the planned and engineered environment differ from professional expectations of precisely how the built environment affects school travel. This kind of asymmetry between the language and concepts of planning or engineering and everyday life represents an important opportunity for education and outreach that probably requires some additional attention in the context of school travel planning and policy.

Beyond previously discussed contributions, this study uniquely focused on the reported (mapped) routes traveled rather than a modeled network shortest path or aggregated buffers. This focus enabled a more fine-grained exploration of the characteristics that children and parents might actually experience or perceive to be enabling or threatening environmental qualities on the trip to and from school. Previous work has determined that safety concerns are common reasons why children are driven, but few studies have examined the actual characteristics and perceptions of safety.

This study also collected data on the traffic around the school to improve the evidence base about the relationship between different qualities of the traffic environment at the school end and school travel mode choice. Traffic volume related to mode choice for the journey to school, and the null finding for traffic mix suggests that, overall, volume is potentially more problematic than vehicle type in regards to mode choice. That is not to say that vehicle type is not important in the context of pedestrian injury or death. Evidence from this study supports the reduction of the numbers of vehicles around schools. School-based policies should aim to remove designated drop-off zones to reduce the number of vehicles around the school and encourage ATS.

ACKNOWLEDGMENTS

This research was funded by the Heart and Stroke Foundation and the Canadian Institutes of Health Research (principal investigators, G. E. J. Faulkner and R. N. Buliung), along with the Canadian Institutes of Health Research, in partnership with the Public Health Agency of Canada (doctoral research award to K. Larsen) and a Canadian Institutes of Health Research Training Grant in Population Intervention for Chronic Disease Prevention: A Pan-Canadian Program. Special thanks go to everyone who helped with the Built Environment and Active Transport project.

REFERENCES

1. Shields, M. Overweight and Obesity Among Children and Youth. *Statistics Canada: Health Reports,* Vol. 17, 2006, pp. 27–42.
2. Buliung, R. N., R. Mitra, and G. Faulkner. Active School Transportation in the Greater Toronto Area, Canada: An Exploration of Trends in Space and Time (1986–2006). *Preventive Medicine,* Vol. 48, 2009, pp. 507–512.
3. McDonald, N. C., A. L. Brown, L. M. Marchetti, and M. S. Pedroso. U.S. School Travel, 2009: An Assessment of Trends. *American Journal of Preventive Medicine,* Vol. 41, 2011, pp. 146–151.
4. Wang, Y. Disparities in Pediatric Obesity in the United States. *Advances in Nutrition,* Vol. 2, 2011, pp. 23–31.
5. Goran, M. I. Energy Expenditure, Body Composition, and Disease Risk in Children and Adolescents. *Proceedings of the Nutrition Society,* Vol. 56, 2008, pp. 195–209.
6. Murtagh, E. M., and M. H. Murphy. Active Travel to School and Physical Activity Levels of Irish Primary School Children. *Pediatric Exercise Science,* Vol. 23, 2011, pp. 230–236.
7. Ewing, R., W. Schroeer, and W. Greene. School Location and Student Travel: Analysis of Factors Affecting Mode Choice. In *Transportation Research Record: Journal of the Transportation Research Board, No. 1895,* Transportation Research Board of the National Academies, Washington, D.C., 2004, pp. 55–63.
8. McMillan, T. E. The Relative Influence of Urban Form on a Child's Travel Mode to School. *Transportation Research Part A,* Vol. 41, 2007, pp. 69–79.
9. Larsen, K., J. Gilliland, P. Hess, P. Tucker, J. Irwin, and M. He. The Influence of the Physical Environment and Sociodemographic Characteristics on Children's Mode of Travel to and from School. *American Journal of Public Health,* Vol. 99, 2009, pp. 520–526.
10. Mitra, R., R. N. Buliung, and M. J. Roorda. Built Environment and School Travel Mode Choice in Toronto, Canada. In *Transportation Research Record: Journal of the Transportation Research Board,*

No. 2156, Transportation Research Board of the National Academies, Washington, D.C., 2010, pp. 150–159.

11. Mitra, R., and R. N. Buliung. Built Environment Correlates of Active School Transportation: Neighborhood and the Modifiable Areal Unit Problem. *Journal of Transport Geography,* Vol. 20, 2012, pp. 51–61.
12. McDonald, N. C., and A. E. Aalborg. Why Parents Drive Children to School. *Journal of the American Planning Association,* Vol. 75, 2009, pp. 331–342.
13. Faulkner, G. E. J., V. Richichi, R. N. Buliung, C. Fusco, and F. Moola. What's "Quickest and Easiest?": Parental Decision Making About School Trip Mode. *International Journal of Behavioral Nutrition and Physical Activity,* Vol. 7, 2010, p. 62.
14. Ahlport, K. N., L. Linnan, A. Vaughn, K. R. Evenson, and D. S. Ward. Barriers to Facilitators of Walking and Bicycling to School: Formative Results from the Non-Motorized Travel Study. *Health Education and Behavior,* Vol. 35, 2008, pp. 221–244.
15. Wen, L. M., D. Fry, C. Rissel, H. Dirkis, A. Balafas, and D. Merom. Factors Associated with Children Being Driven to School: Implications for Walk to School Programs. *Health Education Research,* Vol. 23, 2008, pp. 325–334.
16. Greves, H. M., P. Lozano, L. Lenna, K. Busby, J. Cole, and B. Johnston. Immigrant Families' Perceptions on Walking to School and School Breakfast: A Focus Group Study. *International Journal of Behavioral Nutrition and Physical Activity,* Vol. 4, 2007, p. 64.
17. Collins, D. C. A., and R. A. Kearns. The Safe Journeys of an Enterprising School: Negotiating Landscapes of Opportunity and Risk. *Health and Place,* Vol. 7, 2002, pp. 293–306.
18. Boarnet, M. G., K. Day, C. Anderson, T. McMillan, and M. Alfonzo. California's Safe Routes to School Program: Impacts on Walking, Bicycling, and Pedestrian Safety. *Journal of the American Planning Association,* Vol. 71, 2005, pp. 301–317.
19. Schlossberg, M., J. Greene, P. P. Phillips, B. Johnson, and B. Parker. School Trips: Effects of Urban Form and Distance on Travel Mode. *Journal of the American Planning Association,* Vol. 72, 2006, pp. 337–346.
20. Frank, L., J. Kerr, J. Chapman, and J. Sallis. Urban Form Relationships with Walk Trip Frequency and Distance Among Youth. *American Journal of Health Promotion,* Vol. 21, 4 Suppl., 2007, pp. 305–311.
21. Kerr, J., L. Frank, J. F. Sallis, and J. Chapman. Urban Form Correlates of Pedestrian Travel in Youth: Difference by Gender, Race-Ethnicity and Household Attributes. *Transportation Research Part D,* Vol. 12, 2007, pp. 177–182.
22. Timperio, A., D. Crawford, A. Telford, and J. Salmon. Perceptions About Local Neighborhood and Walking and Cycling Among Children. *Preventive Medicine,* Vol. 38, 2004, pp. 39–47.
23. Ulfarsson, G. F., and V. N. Shankar. Children's Travel to School: Discrete Choice Modeling of Correlated Motorized and Nonmotorized Transportation Modes Using Covariance Heterogeneity. *Environment and Planning B: Planning and Design,* Vol. 35, 2008, pp. 195–206.
24. Larsen, K., J. Gilliland, and P. M. Hess. Route Based Analysis to Capture the Environmental Influences on a Child's Mode of Travel Between Home and School. *Annals of the Association of American Geographers,* Vol. 102, 2012, pp. 1–18.
25. Dalton, M. A., M. R. Longacre, K. M. Drake, L. Gibson, A. M. Adachi-Mejia, K. Swain, H. Xie, and P. E. Owens. Built Environment Predictors of Active Travel to School Among Rural Adolescents. *American Journal of Preventive Medicine,* Vol. 40, 2011, pp. 312–319.
26. DiMaggio, C., and G. Li. Roadway Characteristics and Pediatric Pedestrian Injury. *Epidemiologic Reviews,* Vol. 34, 2012, pp. 46–56.
27. Sze, N. N., and S. C. Wong. Diagnostic Analysis of the Logistic Model for Pedestrian Injury Severity in Traffic Crashes. *Accident Analysis and Prevention,* Vol. 39, 2007, pp. 1267–1278.
28. Zegeer, C. V., and M. Bushell. Pedestrian Crash Trends and Potential Countermeasures from Around the World. *Accident Analysis and Prevention,* Vol. 44, 2012, pp. 3–11.
29. Lefler, D. E., and H. C. Gabler. The Fatality and Injury Risk of Light Truck Impacts with Pedestrians in the United States. *Accident Analysis and Prevention,* Vol. 36, 2004, pp. 295–304.
30. Buliung, R. N., K. Larsen, G. E. J. Faulkner, and M. Stone. The "Path" Not Taken: Route Discordance in School Travel Research. *American Journal of Public Health,* forthcoming.
31. Box, C. P., and J. C. Oppenlander. Traffic Volumes. In *Manual of Traffic Engineering Studies,* ITE, Arlington, Va., 1976.
32. Tay, R. Marginal Effects of Changing the Vehicle Mix on Fatal Crashes. *Journal of Transport Economics and Policy,* Vol. 37, 2003, pp. 439–450.
33. *Vehicle Weight, Fatality Risk and Crash Compatibility of Passenger Cars and Light Trucks.* NHTSA, U.S. Department of Transportation, Springfield, Va., 2003.
34. *MOVES2010 Highway Vehicle: Population and Activity Data.* U.S. Environmental Protection Agency, 2010. http://www.epa.gov/otaq/models/moves/420r10026.pdf Accessed June 1, 2012.
35. Lockwood, I. M. ITE Traffic Calming Definition. *ITE Journal,* July 1997, pp. 22–24.
36. Bunn, F., T. Collier, C. Frost, K. Ker, R. Steinbach, I. Roberts, and R. Wentz. Area-Wide Traffic Calming for Preventing Traffic Related Injuries. *Cochrane Database of Systematic Reviews.* John Wiley & Sons, Ltd., London, 2009, pp. 1–39.
37. Schimek, P. Household Motor Vehicle Ownership and Use: How Much Does Residential Density Matter? In *Transportation Research Record 1552,* TRB, National Research Council, Washington, D.C., 1996, pp. 120–125.

The Transportation Safety Management Committee peer-reviewed this paper.