JTLU

School travel route measurement and built environment effects in models of children's school travel behavior

Author(s): Kristian Larsen, Ron N. Buliung and Guy Faulkner

Source: *Journal of Transport and Land Use*, 2016, Vol. 9, No. 2 (2016), pp. 5-23

Published by: Journal of Transport and Land Use

Stable URL: https://www.jstor.org/stable/26203218

The Journal of Transport and Land Use http://jtlu.org
Vol. 9 No. 2 [2016] pp. 5–23

School travel route measurement and built environment effects in models of children's school travel behavior

Kristian Larsen
University of Toronto
kristian.larsen@utoronto.ca

Ron N. Buliung
University of Toronto Mississauga
ron.buliung@utoronto.ca

Guy Faulkner
University of Toronto
guy.faulkner@utoronto.ca

Abstract: The most common form of physical activity for people of all ages is walking, thus the use of active travel modes, such as walking or cycling for school trips, can increase daily physical activity levels. School travel is one way to encourage walking and cycling on a daily basis. Much of the recent literature reports inconsistent results pertaining to how the built environment may relate to active school travel. To date, there is no consistent approach toward conceptualizing the "environment" for its measurement, and this may be partially to blame for the inconsistent results. The purpose of this paper is twofold: to examine how characteristics of the built environment might relate to mode of school travel, while testing how measurement of the environment may influence the results in terms of the shortest path or respondent reported route mapping. The results indicate that model parameter estimates vary when using these two route measurement methods. Differences in the conceptualization and measurement of the school travel environment could carry forward into misguided planning or policy interventions targeting environmental features that may actually have no influence on school travel decisions.

Keywords: School travel, GIS, built environment, measurement issues

Article history:
Received: September 17, 2014
Accepted: January 28, 2015
Available online: July 14, 2015

1 Introduction

Over the past decade, several studies have examined how the built environment relates to children's school travel patterns (McMillan 2007; Faulkner et al. 2009; Panter et al. 2011; Larsen, Gilliland, and Hess 2012). That research was largely motivated by the precipitous decline in children's physical activity that has taken place in much of the Global North during the post World War II era. As an example, only 7 percent of Canadian children ages 5 to 11 and 4 percent of 12- to 17-year-olds are active enough to meet the national physical activity guidelines (Active Healthy Kids Canada 2013). There are

http://dx.doi.org/10.5198/jtlu.2015.782
ISSN: 1938-7849

The *Journal of Transport and Land Use* is the official journal of the World Society for Transport and Land Use (WSTLUR) and is published and sponsored by the University of Minnesota Center for Transportation Studies. This paper is also published with sponsorship from WSTLUR and the Institutes of Transportation Studies at the University of California, Davis, and the University of California, Berkeley.

many problems associated with not being physically active. Low levels of physical activity can lead to an increased risk of obesity and other chronic diseases (Trost et al. 2001; Janssen and LeBlanc 2010). Establishing physical activity at a young age is particularly important; physically active children are more likely to remain active throughout their lives (Telama et al. 2005; Conroy et al. 2005).

Active school travel (AST), which includes walking, cycling, and other modes involving self locomotion, is one important source of physical activity for children (Lee, Orenstien, and Richardson 2008; Morency and Demers 2010; Larouche et al. 2012). Research consistently demonstrates that children who walk or bike to school are more physically active than those who are driven, although the evidence is less consistent regarding the relationship between active school travel and healthier body weights (Sirard and Slater 2008; Faulkner et al. 2009; Larouche et al. 2012).

A focus of recent research is on how the built environment may facilitate or hinder walking or cycling to and from school. When looking across this literature, inconsistent results are reported on environmental correlates of walking. A recent paper by Kwan (2012) highlights the importance of measurement and the uncertain geographic context problem (UGCoP). UGCoP relates to how area-based characteristics are influenced by the contextual geographic unit used to examine the environment (i.e., buffer, census tract, route), and that the unit applied may not be the best unit of measurement (Kwan 2012). Different geographical units of measurement may produce varying results. In regard to obesity and the environment, different units of measurement commonly produce inconsistent findings (Inagami, Cohen, and Finch 2007; Black and Macinko 2008; Wilks et al. 2010). There has been very little work to date examining how UGCoP relates to school travel; however, findings from previous work have reported route differences in structural characteristics between the shortest-path route estimates and respondent-reported mapped route data (Buliung et al. 2013). The purpose of this study is twofold: to first examine how characteristics of the built environment may relate to school travel mode choice; and second to examine how differences in GIS-based methods for environmental measurement impact model estimation. To this end, the environment is differentially measured along the shortest path between home and school and along routes that have been mapped by survey respondents. The shortest-path approach is commonly applied to environmental assessment in school travel modeling in the absence of other route data (Schlossberg et al. 2006; Timperio et al. 2006; Panter et al. 2011; Larsen, Gilliland, and Hess 2012).

2 Literature review

Children's school travel mode share has changed considerably over the past 50 years in much of the Global North. Rates of active travel to and from school have decreased, while sedentary travel in a motor vehicle has become increasingly common (McDonald 2007; Buliung, Mitra, and Faulkner 2009; McDonald et al. 2011). Switching from a sedentary activity such as being driven to school to an active one such as walking may influence overall activity levels. Increasing physical activity levels are important, as daily activity may be one of the best measures to tackle the prevalence of childhood overweight and obesity (Kwon et al. 2013).

Findings from previous work have found a relationship between certain environmental features and travel mode (Kerr et al. 2007; Larsen et al., 2009; Mitra, Buliung, and Roorda 2010; Panter et al. 2010b), although much of the work has produced inconsistent results. There are three methods commonly applied in the current literature to "conceptualize" the environment for its objective measurement: neighborhood buffers, the shortest path, or the mapped route. It is unknown which is the most appropriate approach, as route based, shortest path, and broad environmental features may all be related to travel decisions to some degree; there may also be a geographical and temporal scaling of environmental effects.

Several studies use aggregated buffers of the home and/or school neighborhood (Braza, Shoemaker, and Seeley 2004; Kerr et al. 2006; Frank et al. 2007; McMillan 2007; Larsen et al. 2009). In these studies the school or home is buffered using a selected radial distance. At a conceptual level, the underlying assumption is that the environment within the neighborhood buffer captures some of the design elements influencing school travel decisions. This aggregated approach will capture environmental characteristics children interact with, but also other features, which may be unrelated to their school trip. Conceptually, this method does not accurately measure the environment children are exposed to while traveling to and from school, but it does pick up on environmental characteristics in their home/school neighborhood that may influence environmental perceptions. In relation to health outcomes, residential neighborhood features may not directly relate to health behaviors (Diez-Roux 1998; Cummins 2007; Matthews 2008; Chaix 2009; Kwan 2009) but may influence parental perceptions, which in turn influence the health behaviors of children, for example.

More recently, studies have measured the environment using the shortest path between a child's home and school (Schlossberg et al. 2006; Timperio et al. 2006; Panter et al. 2010; Panter et al. 2011; Larsen, Gilliland, and Hess 2012). The shortest path may be an improvement over previous methods because its use assumes a conceptual move away from origin/destination environmental exposure only. However, its use also assumes that a child travels along the shortest route for school travel, which may not always be the case (Buliung et al. 2013). For example, some children may actually take a longer or less direct route to walk with friends, avoid conflicts with other children, or to avoid major streets or intersections.

Finally, building on the focus on the route to and from school, one recent study has examined characteristics along the drawn or mapped route in relation to mode of travel (Larsen, Buliung, and Faulkner 2013). This paper adds to previous work by exploring the possible impact of route measurement approaches on the parameter estimates of school travel models. Reported route-based methods could more accurately capture environmental characteristics that children actually interact with, but it is unknown how reported routes relate to perceptions of the environment or school travel decisions.

Findings from shortest path and route-based studies suggest that the environment may relate to travel mode. Timperio et al. (2006) discovered that for 5- and 6-year-olds (n=235) along with children aged 10 to 12 (n=677) distance and busy street crossings negatively influenced rates of walking to school within a sample of 19 elementary schools in Melbourne, Australia. Street connectivity was also a negative factor for children aged 10 to 12, while neighborhood income was not significant for either age group (Timperio et al. 2006).

In Oregon, features associated with the street network related to walking for children in grades six, seven, and eight (n=287), where lower street connectivity and a higher concentration of cul-de sac's both negatively influenced walking rates to and from school (Schlossberg et al. 2006). That study examined four different schools stratified by income and era of development. One school was located in an area with lower-than-average neighborhood income and a more suburban environment, while another school was in a lower-income but older area. The two other schools were in above-average income areas, one being in a newer more suburban area, while the other was in an older neighborhood.

In the UK, a higher road density increased the odds of walking, while having a route that was more direct, negatively related to walking for 9- and 10-year-old children (n=2064) living in Norfolk County (Panter et al. 2010). Children living in more deprived areas were also less likely to walk to school. The sample consisted of 92 different schools throughout the county in areas of varying income and environments.

Finally, findings from a Canadian study of seventh- and eighth-grade students (n=614) found that factors such as distance and higher traffic volumes negatively associated with walking for both school trips. Other features such as land-use mix, residential density, and street trees associate with AST in the morning, while for the trip home from school, neighborhood income and major street crossings decreased the odds of walking/cycling (Larsen, Gilliland, and Hess 2012). This sample consisted of 21 schools in London, Ontario, in neighborhoods of contrasting built and social environments.

More recently, when the mapped route was examined, a higher number of vehicles around the school, higher number of street crossings, incomplete sidewalk networks, and the presence of parking facilities emerged as potentially important objective correlates negatively associated with walking (Larsen et al. 2013). Overall, the literature on school travel mode choice produces inconsistent findings on the relationship between environmental correlates and mode outcomes. There is also a knowledge gap with regard to understanding the psychosocial and/or cognitive construction of environmental perceptions, and how such perceptions align with our state of practice approaches to modeling urban design. This study focuses on the measurement issue by examining variation in parameter estimates of explanatory models of mode choice by route measurement methods; namely, the shortest path or respondent reported route mapping. Understanding such measurement effects is important to the development of an evidence base that may be used to construct meaningful interventions targeting the appropriate environmental features.

3 Methods

This section begins by discussing the conceptual framework guiding this research, followed by the primary data collection process, GIS analysis, exploration of the traffic environment and statistical modeling. This research is set within a social-ecological framework. Within a social-ecological framework a connection is conceptualized between travel behavior and one's social and physical environments. The main concept of an ecological framework relates to the nesting of multiple levels of influences from the individual to community features or the broader environment (Sallis, Owne, and Fisher 2008; van Loon and Frank 2011). Typically, ecological frameworks include four or more levels of influence, related to the individual, social/cultural environment, built environment, and policy environment. These levels interact with one another and, in turn, as we hypothesize here, relate to walking and physical activity levels. Under the application of the ecological framework, specific environmental (objective and perceived), social, individual, and policy characteristics were examined in this study. Table 1 illustrates each of the variables examined, how they relate to the ecological framework, and how the data were collected.

Table 1: Variables examined in relation to the ecological framework

Variables:	Level of influence:	Data collected from:
Age	Individual	Individual surveys (parents and children)
Gender	Individual and social/cultural environment	Individual surveys (parents and children)
Distance	Individual, built and policy environment	GIS (Mapped route and shortest path)
Intersections	Built and policy environment	GIS (Mapped route and shortest path)
Major crossings	Built and policy environment	GIS (Mapped route and shortest path)
Proportion missing sidewalks	Built and policy environment	GIS (Mapped route and shortest path)
Maximum traffic	Built and policy environment	Traffic counts (Mapped route and shortest path)
Land-use mix	Built and policy environment	GIS (Mapped route and shortest path)
Traffic calming density	Built and policy environment	GIS (Mapped route and shortest path)
Vehicle fleet index	Built and policy environment	Traffic counts (Mapped route and shortest path)
Home DA income	Social/cultural environment	Census
Street tree density	Built and policy environment	GIS (Mapped route and shortest path)
Parking facilities	Built and policy environment	Field surveys
Vehicles per licensed driver	Individual and social/cultural environment	Individual surveys (parents and children)

Data collection for this study was completed in Toronto, Canada's largest city, as part of the Built Environment and Active Transportation (BEAT) project. In January 2010, all elementary school principals (for schools with grades five and six) within the Toronto District School Board (TDSB) received an invitation to participate (n=469). From the pool of interested principals (n=40; response rate of 11.5 percent), selective sampling took place to target schools in neighborhoods of contrasting built environment and income levels. Schools were manually targeted with respect to built form (i.e., newer areas with curvilinear street networks versus older neighborhoods with a gridded street layout) and socioeconomic status (low- and high-income households based on median household income reported in the 2006 Canadian Census). Half of the surveyed schools were low SES, and the other half were high SES; similarly, eight schools were in older neighborhoods and eight were in newer inner-suburban areas.

Of the 1704 students enrolled in grades five and six at the 16 participating schools, 1027 (60.3 percent) completed the travel behavior survey and were given consent to participate in the study by their parents/guardians; missing responses resulted from parent or student refusal. Following initial instruction, fifth and sixth grade students (n=1001, 26 were absent on day of data collection) completed activity-travel behavior surveys. Child and parental surveys were used to obtain the mode of travel to and from school along with socio-demographic information. Students and parents completed consent forms prior to data collection.

Children brought home a parental survey, and a map of their home neighborhood with their home and school highlighted. Participants were asked to draw their "typical" route to and from school to complete the mapping exercise. Typical was defined as what the child did on a regular basis. Both children and their parents completed the mapping exercise together. Heads-up digitizing was used to generate digital Geographic Information Systems (GIS)-based to and from routes with the assistance of 20-centimeter resolution aerial photography and field surveys when necessary. Every route was manually converted from the drawn paper map to a digitized vector GIS route producing 978 school route maps.

The digitized route maps allow for exploration of objective environmental characteristics along each child's reported route. Home addresses were obtained from the child and parent consent forms and used to estimate the shortest path between a child's home and school. Different shortest paths were created for walkers and for children who were driven. Walkers' shortest paths were built using a circulation system network including roadways, trails, and multi-use pathways; no direction restrictions were applied. For walking routes, distance was the method of impedance applied, suggesting that children will take the shortest trip by distance. For children who were driven to school, the shortest path was calculated along the road network and restrictions for one-way streets and illegal turns were included. Time was used as the method of impedance for children being driven, assuming that driving adults will take the shortest route according to time rather than distance (Faulkner et al. 2010). Figure 1 shows a hypothetical comparison of the shortest path to school versus the mapped route reported on the mapping exercise. To ensure anonymity, neither the household nor the school participated in the study and all street names are fictitious.

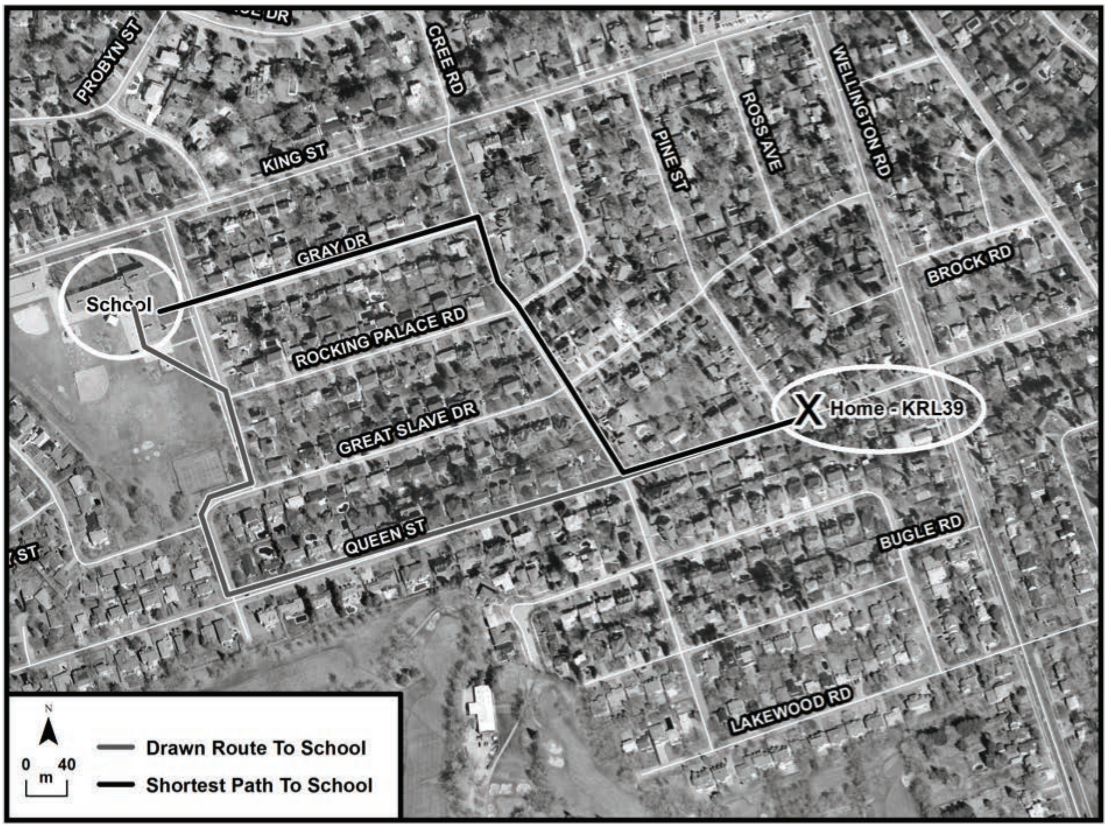

Figure 1: Hypothetical example of a drawn route completed in the mapping exercise versus the shortest path

4 Detailed assessment of the routes to and from school and the shortest path

Data on sidewalks, street trees, traffic-calming devices, and the street network were obtained from the city of Toronto and used to measure various characteristics along the routes between home and school. Ground truthing of all datasets involved field survey and the use of aerial photography. The use of the route based analysis allowed researchers to obtain measured data on the distance between home and school. All environmental variables were computed separately for the mapped routes and shortest paths.

Environmental characteristics were selected on the basis what has been studied in the literature and also through a process of reflecting on school travel decisions and outcomes using a socio-ecological framework (Sallis, Owne, and Fisher 2008; van Loon and Frank 2011). The density of all types of intersections crossed was calculated based on the distance each child travels (to give a density or number of street crossings per route kilometer) and repeated for major streets only. Classification of major intersections consists of arterial streets (major or minor arterial) as defined by the city of Toronto (City of Toronto, 2010). Both of these variables may be related to traffic safety and a child's ability to maneuver through the environment. No consistent connection exists regarding street crossings and mode of travel for children (Schlossberg et al. 2006; Kerr et al. 2006; Larsen, Gilliland, and Hess 2012). Conceptually it makes sense to consider that the accumulation of street crossings en route could arise as a safety concern for some parents, affecting the mode choice decision.

A few recent studies have found a link between street trees and active travel to school (Larsen et al. 2009; Larsen, Gilliland, and Hess 2012), but more work is needed to understand the relationship between the urban forest and transport decisions as no conclusive evidence exists. The proportion of missing sidewalks was compiled by identifying the length of sidewalks missing on both sides of the street in relation to the length of the trip (i.e., finding the proportion of route with missing sidewalks). Sidewalks may be an important characteristic of pedestrian safety as they give people space away from moving vehicles. The density of traffic calming devices (chicanes, speed bumps, raised intersections, etc.) was also examined in relation to the distance traveled. These features may slow traffic and reduce safety concerns by lowering the perceived and or actual risk of severe injury or death.

Lower-income neighborhoods commonly have a higher incidence of child pedestrian injury (DiMaggio and Li 2012), but also have higher rates of walking (Larsen, Gilliland, and Hess 2012). Since no individual-level income variable was available, the median household income from the home dissemination area (DA) was applied based on the home address. Dissemination areas are the smallest spatial unit where income-level data is available in Canada. DAs are a relatively stable geographical unit, typically contain only a few blocks in urban areas such as Toronto, and have a population ranging between 400 and 700 persons. The mean size of a DA in Toronto is 0.187 kilometers^2.

Land-use mix is often measured using an entropy index based on the area of land dedicated to particular uses (Larsen, Gilliland, and Hess 2012). This study examines the actual route traveled and in turn applies a new route-based approach to examine land-use mix along the property frontages for each child's route/shortest path. This method uses the same approach as previous work (Kerr et al. 2006; Larsen, Gilliland, and Hess 2012) but at a different spatial scale due to the route-based nature of this paper. 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/shortest path and an entropy approach was used to represent land-use mix using the following formula:

$$[\text{Land Use Mix} = -\sum lu\ (\rho u \ln \rho u) \,/\, \ln n]$$

where $\boldsymbol{lu}$ is the land use, $\boldsymbol{\rho u}$ is the proportion of parcel frontage within a land-use category, and $\boldsymbol{n}$ is the total number of land-use classes. Values range from 0 to 1, with 0 representing a route populated by a single land use and 1 indicating presence and equal distribution of all five land-use classes.

5 Individual and social characteristics

Gender is one of the most common factors associated with mode choice for school travel (Yarlagadda and Srinivasan 2008; Mitra et al. 2010; McDonald 2011; Larsen, Gilliland, and Hess 2012). Recognizing that there are problems and complexity with essentializing "gender," the literature typically indicates that boys are more likely to walk and have independent mobility than girls. There is an important literature on how these gender differences arise, a literature that typically qualitatively explores intersections between risk, mobility, and the gendered quality of "good" parenting and childhood (Murray 2009;

Buliung et al. 2015). While the modeling literature indicates a persistent gender gap from study to study, the qualitative literature points to a possible causal pathway as the gender, risk, and mobility experiences of parents become somewhat mirrored in children's transport (Murray 2009; Buliung et al. 2015). Age also relates to mode choice, with older children more likely to walk than others (Mitra, Buliung, and Roorda 2010). The availability of automobiles is also an important household characteristic. If a household does not own or have access to a working vehicle, it may not be possible to drive the child to school. Vehicle ownership was found to be related to travel mode in one study (Vovsha and Petersen 2005), but Schlossberg et al. (2006) found no relationship. The number of vehicles per licensed driver variable used a ratio based on the responses from the parent survey.

6 Traffic counts

No conclusive empirical evidence exists regarding the relationship between school travel and traffic conditions. Manual traffic counts were conducted to collect data on the number and type (cars, truck, bus, etc.) of vehicles at all access and egress points around the schools. This approach provides traffic data for the entire block surrounding the school, and helps to obtain an idea of traffic conditions around the school. Previous work suggests that higher traffic volume is the largest concern for pedestrians of all ages (Zegeer and Bushell 2012). To be consistent with the findings from the pedestrian safety literature (Zegeer and Bushell 2012), the traffic volume at the intersection that had the highest number of vehicles (or maximum traffic) along each route or shortest path was the measure of traffic volume applied to each student. Underlying this approach is the assumption that the maximum traffic volume or worst-case scenario would most likely affect school travel decisions.

No known vehicle index or multiplier exists for linking vehicle fleet characteristics with pedestrian safety. To understand how different types of vehicles relate to walking, a vehicle fleet index was created. Separate traffic-volume data for each vehicle type could not be applied, as these values were highly correlated. For pedestrian safety, the difference between smaller and larger motor vehicles relates to vehicle mass and speed. To account for vehicle size, a multiplier (based on average vehicle weights) was applied to obtain car equivalents for each vehicle type (NHTSA 2003). The measure of passenger vehicles consisted of the weighted SUV/minivan totals and the number of cars. The following multipliers were applied: car, 1.0; SUV/minivan, 1.3; bus,11.2; school bus, 6.1; and truck, 13.2. Four vehicle classification types (passenger, transit, school bus, truck) were used to create the fleet index. A reverse entropy index was calculated to represent the mix of vehicles around each of the sampled schools using the following formula:

$$[\text{Fleet mix} = (v\ (\mathrm{p}v \ln \mathrm{p}v) / \ln n) + 1],$$

where $\boldsymbol{v}$ is the type of vehicle; $\boldsymbol{p}$ is the proportion of the vehicle type dedicated to that classification; and $\boldsymbol{n}$ is the total number of classifications (n=4: passenger vehicles, transit, school bus, and trucks). Fleet-mix scores range from 0 to 1. Zero represents a mix dominated by trucks, transit and school buses, while a score of 1 represents only passenger vehicles.

7 Data analysis

Initial analysis determined that statistical outliers for many of the environmental variables were most commonly found for children having route distances greater than 1.6 kilometers (1 mile); thus only children living within 1.6 kilometers of school (measured distance on their mapped route) were included in this analysis. Furthermore, there were not enough cases for children cycling, taking transit, or riding a school bus, so these cases were also excluded reducing the sample to 687 students. For comparative purposes, the analysis for the shortest path used the same 687 respondents. Univariate logistic regression (walk vs. driven) was first used to determine unadjusted associations with walking. Separate tests were completed for the shortest path and mapped routes along with the trips to and from school. Table 2 displays how each feature relates to walking and the differences between the methods of route measurement. Variables were entered into adjusted models if they were significant at $p<0.05$ in either the shortest path or mapped route univariate testing. Following initial analysis, all variables within the models were tested for multicollinearity issues.

Table 2: Significance of correlations to walking in preliminary univariate analysis

Variable	To school				From school			
	Mapped		Shortest path		Mapped		Shortest path	
	p value	*Direction*	*p value*	*Direction*	*p value*	*Direction*	*p value*	*Direction*
Age	**0.101**	-	0.101	-	0.916	+	0.916	+
Gender (girls as referent)	**0.002**	+	**0.002**	+	**0.005**	+	**0.005**	+
Distance	**<0.001**	-	**<0.001**	-	**<0.001**	-	**<0.001**	-
Intersections	**<0.001**	-	0.432	-	**<0.001**	-	0.693	-
Major crossings	**0.010**	-	**0.005**	-	0.480	-	0.908	-
Proportion missing sidewalks	**<0.001**	-	**<0.001**	-	0.070	-	**<0.001**	-
Maximum traffic	**<0.001**	-	**0.007**	-	**0.005**	-	**<0.001**	-
Land-use mix	**<0.001**	-	**<0.001**	+	**<0.001**	-	0.109	+
Traffic-calming density	**0.015**	+	**0.004**	+	0.729	-	0.161	+
Vehicle fleet index	0.127	+	**<0.001**	+	0.239	-	**<0.001**	+
Home DA income	**0.016**	-	**0.016**	-	**0.004**	-	**0.004**	-
Street tree density	0.096	+	**0.016**	+	**0.032**	+	**0.023**	+
Parking facilities	0.302	-	0.302	-	**<0.001**	-	**<0.001**	-
Vehicles per licensed driver	**0.018**	-	**0.018**	-	0.068	-	0.068	-

Significant variables in bold.

8 Model specification

Separate binomial logistic regression models were estimated for shortest path and mapped route to examine how characteristics of the environment relate to mode of travel with walking as the dependent variable. The purpose of these models is to explain how the environment may relate to mode choice and to assess how differences in environmental measurement influence estimation results. Given the common finding that correlates of walking are different across the morning and afternoon school trips (e.g., Larsen et al. 2009; Mitra, Buliung, and Roorda 2010; Larsen, Gilliland, and Hess 2012), separate models were also estimated for the trips to and from school. A difference of means t-test was applied to test for differences in the coefficients produced from the mapped route and shortest-path models.

9 Results

Following the reporting of descriptive statistics, results are presented for the modeled mode choice analysis for the mapped route to and from school, followed by the shortest path results and a brief comparison. The sample included 687 children, as missing data, living beyond a distance of 1.6 kilometer, or taking infrequently cited alternative modes of transport, resulted in the exclusion of 314 cases. Rates of walking were high for both the trip to (n=538, 78 percent) and from school (n=585, 85 percent). There were fewer children being driving home from school (n=102) than to school (n=149) (Table 3). The sample included 359 girls and 328 boys. The median household income of the respondents home DA was $72,932 (which is comparable to the Toronto average median household income of $74,312) and there was a median of one vehicle per licensed driver within the sample.

The median distance was 587 meters for both the trip to and from school along the mapped routes; distances for the shortest-path analysis were typically longer (620 meters to school and 613 meters from school). Each mapped route crossed an average of about five streets, although very few of these streets would be classified as a major road (1.44 mean). The shortest path crossed seven or more intersections, but again very few were major. Each route interacted with more vehicles in the morning trip, regardless of the method of measurement, but the shortest path analysis produced routes with greater traffic volume.

Table 3: Descriptive statistics for participant routes

To school	Mapped				Shortest path		
Variable	**Mean**	**Median**	**SD**	**n**	**Mean**	**Median**	**SD**
Mode of travel: Walking	---	---	---	538	---	---	---
Mode of travel: Driven	---	---	---	149	---	---	---
Gender: Girls	---	---	---	359	---	---	---
Gender: Boys	---	---	---	328	---	---	---
Distance to school (m)	656.51	587.23	369.49	687	682.03	620.08	365.67
Intersections crossed on route	5.69	5.79	3.24	687	7.69	7.52	2.90
Major street crossings on route	1.44	0.00	2.43	687	1.86	0.00	2.65
Maximum traffic on route	443.09	253.00	518.15	687	557.55	291.00	565.34
Vehicle fleet index	0.45	0.42	0.19	687	0.56	0.58	0.18
Missing sidewalks	0.03	0.00	0.10	687	0.06	0.00	0.23
Street tree density	76.48	72.13	65.13	687	100.01	86.78	73.08
Income $CDN	71 564.13	72 932.00	38 827.92	687	71 564.13	72 932.00	38 827.92
Traffic-calming density	0.56	0.00	1.40	687	0.79	0.00	1.80
Vehicles per licensed driver	0.86	1.00	0.28	687	0.86	1.00	0.28
Land-use mix	0.21	0.14	0.23	687	0.28	0.29	0.22
From School							
Mode of travel: Walking	---	---	---	585	---	---	---
Mode of travel: Driven	---	---	---	102	---	---	---
Gender: Girls	---	---	---	359	---	---	---
Gender: Boys	---	---	---	328	---	---	---
Distance to school (m)	655.94	587.07	368.90	687	682.56	612.66	371.60
Intersections crossed on route	5.52	5.59	3.26	687	7.66	7.53	2.90
Major street crossings on route	1.29	0.00	2.25	687	1.73	0.00	2.52
Maximum traffic on route	378.09	215.00	474.39	687	548.90	267.00	650.28
Vehicle fleet index	0.35	0.34	0.26	687	0.58	0.64	0.19
Missing sidewalks	0.03	0.00	0.10	687	0.05	0.00	0.18
Street tree density	82.20	77.75	61.30	687	100.94	88.31	72.38
Income $CDN	71 564.13	72 932.00	38 827.92	687	71 564.13	72 932.00	38 827.92
Traffic-calming density	0.63	0.00	1.59	687	0.79	0.00	1.85
Vehicles per licensed driver	0.86	1.00	0.28	687	0.86	1.00	0.28
Land-use mix	0.20	0.10	0.22	687	0.28	0.29	0.22

Both the mean and median values for maximum traffic were higher in the shortest-path analysis. Along the mapped routes, there were more passenger vehicles around the school in the morning, while the shortest-path analysis suggests that vehicle mix is similar for both trips. Most of the routes, regardless of the spatial unit of measurement, had a complete sidewalk network with an abundance of street trees. Traffic-calming devices were not evident on every route, but over half of all routes had some form of traffic-calming device and traffic calming was more prominent along the shortest paths. Overall, the descriptive analysis suggests that the shortest path produces school travel environments that typically have a longer route, crossing more streets, with greater traffic volume than reported mapped routes.

10 Binomial logistic regression models of school travel mode

10.1 Mapped routes

Along the mapped route, only gender, distance, and intersections crossed were significantly related to walking in both the to- and from-school models (Table 4). Expectedly, as distance increased, the odds of walking decreased. Boys were 1.9 times more likely to walk to school than girls and crossing additional intersections along the route related to a decrease in the odds of walking. For the to-school trip, vehicles per licensed driver decreased the odds of walking, while having traffic-calming features increased the odds of walking to school. For the from-school trip, higher-income households and having an incomplete sidewalk network lowered the odds of walking, while additional street trees along the route associated with walking home from school.

Table 4: Binomial logistic regression analysis with walking versus driving as the dependent variable for the mapped route and shortest path

		Mapped route				Shortest path			Difference of means	
To-school trip	Coefficient	S.E.	p-Value	Odds Ratio	Coefficient	S.E.	p-Value	Odds Ratio	t-diff	p-Value
Gender[a]	**0.660**	**0.231**	**0.004**	**1.936**	**0.814**	**0.244**	**0.001**	**2.257**	---	---
Vehicles per licensed driver	**-1.024**	**0.414**	**0.013**	**0.359**	-0.706	0.413	0.088	0.494	---	---
Income[b]	-0.002	0.003	0.476	0.998	0.004	0.004	0.240	1.004	---	---
Distance (km)	**-3.016**	**0.347**	**<0.001**	**0.049**	**-3.133**	**0.360**	**<0.001**	**0.044**	**-52.556**	**0.012**
Major intersections crossed on route	-0.017	0.055	0.755	0.983	**-0.214**	**0.056**	**<0.001**	**0.807**	-1.173	0.450
Missing sidewalks[c]	-1.508	1.009	0.135	0.221	**-3.344**	**0.782**	**<0.001**	**0.035**	-2.643	0.230
Traffic-calming density	**0.246**	**0.112**	**0.028**	**1.279**	0.165	0.105	0.116	1.179	5.074	0.124
Street tree density	0.002	0.002	0.443	1.002	**0.006**	**0.003**	**0.016**	**1.006**	2.000	0.295
Maximum traffic	-0.033	0.027	0.221	0.967	<0.001	<0.001	0.551	1.000	-1.000	0.500
Intersections crossed on route	**-0.140**	**0.042**	**0.001**	**0.870**	<0.001	0.045	0.098	1.000	-1.000	0.500
Vehicle fleet index	-0.765	3.878	0.844	0.465	**1.896**	**0.722**	**0.009**	**6.656**	0.425	0.744
Land-use mix	0.362	0.611	0.554	1.436	**4.893**	**0.766**	**<0.001**	**133.385**	1.160	0.453
Constant	5.929	3.801	0.119	375.696	1.441	0.773	0.062	4.225	---	---
From-school trip										
Gender[a]	**0.654**	**0.271**	**0.016**	**1.923**	0.412	0.317	0.194	1.510	---	---
Income[b]	**-0.007**	**0.003**	**0.039**	**0.993**	-0.001	0.003	0.722	0.999	---	---
Distance (km)	**-3.373**	**0.409**	**<0.001**	**0.034**	-3.257	0.436	<0.001	0.039	-57.155	0.011
Missing sidewalks[c]	**-3.004**	**1.327**	**0.024**	**0.050**	**-2.496**	**0.799**	**0.002**	**0.082**	**-10.827**	**0.059**
Street tree density	**<0.001**	**<0.001**	**0.007**	**1.001**	**0.010**	**0.004**	**0.012**	**1.010**	1.000	0.500
Maximum traffic	-0.005	0.026	0.856	0.995	**-0.002**	**<0.001**	**<0.001**	**0.998**	-2.333	0.258
Intersections crossed on route	**-0.111**	**0.054**	**0.040**	**0.895**	-0.056	0.822	0.363	0.946	-3.036	0.203
Vehicle fleet index	0.750	0.587	0.201	2.117	**2.527**	**0.061**	**0.002**	**12.511**	1.844	0.316
Land-use mix	-0.342	0.686	0.618	0.710	**5.305**	**0.968**	**<0.001**	**201.254**	**0.879**	**0.541**
Constant	4.705	0.546	<0.001	110.477	3.001	0.963	0.002	20.103	---	---

[a]Female as referent

[b]Home DA level income (CAD$)

[c]Proportion of route with sidewalk missing on both sides of street

R2: To school - 0.39 (mapped route) and 0.46 (shortest path) From school - 0.37 (mapped route) and 0.57 (shortest path)

Variables in **bold** are significant at $p < 0.005$

10.2 Shortest path

When the route-measurement approach shifted to shortest-path estimation, more environmental variables were significantly related to walking for both trips. Distance, sidewalks, street trees, vehicle mix, and land use were significant for both the to- and from-school trips (Table 4). As distance increased, the odds of walking decreased. Routes with missing sidewalks again related to lower odds of walking. A higher density of street trees along the route increased the odds of walking as did a route with more passenger vehicles and mixed land uses. For the to-school trip, boys had higher odds of walking, but this was not significant for the trip home. Crossing major streets while traveling to school lowers the odds of walking, while increased traffic volume around the school in the afternoon also decreased the odds of walking.

10.3 Comparison of models based on mapped and shortest-path route data

The results suggest statistically significant differences in the parameter estimates of several variables between the shortest-path and mapped-route models. The only variable that was significantly related to both the to- and the from-school trips regardless of measurement type was distance. Table 5 displays the similarities and differences between the mapped route and shortest-path models. For the to-school trip, gender and distance were significant correlates irrespective of measurement approach. While on the trip home, distance, missing sidewalks, and street trees were significant regardless of the environmental measurement method, highlighting the significance of these features. Other environmental and individual features correlated with walking, but they were specific to measurement type. In particular, the traffic and land-use variables (land-use mix, maximum traffic volume, and vehicle mix) appear to only be significant in the shortest-path models.

Table 5: Comparison of significant variables from the mapped-route and shortest-path results for walking versus driving (p-value < 0.05)

To school	Mapped route only	Both mapped route and shortest path	Shortest path only
	Vehicles per licensed driver	Gender	Major intersections crossed on route
	Traffic-calming density	Distance	Street tree density
	Intersections crossed on route		Vehicle fleet index
			Land-use mix
			Missing sidewalks
From school			
	Gender	Distance	Maximum traffic on route
	Income	Street tree density	Vehicle fleet index
	Intersections crossed on route	Missing sidewalks	Land-use mix

11 Discussion

The results of this study suggest that the statistical validity of models that include environmental correlates of school travel mode depends on the approach taken and assumptions underlying first the conceptualization of, and then the measurement of, the "environment." Overall, there were more significant variables in the shortest-path analysis and model fit was better than in the mapped route models, but this does not mean that shortest-path analysis is a better method to examine the built environment. The fact that differences were found between the shortest path and mapped route highlights the methodological challenges with school travel research and is a contribution to the current literature. Given that much of the intervention discourse remains primarily fixated on environmental change, illustrating that the standard practice of using shortest-path analysis for environmental measurement produces parameter estimates different from reported route mapping is a profoundly meaningful result. The evidence base on the environmental correlates of school travel is clearly wrought with uncertainty and problems with statistical validity as this study demonstrates.

Differences in the shortest-path and mapped-route analysis demonstrate the importance of thinking about the presence of the uncertain geographic context problem within school travel research. Considering downstream effects with regard to knowledge transfer, research in school transport is being taken up in practice and discussed in the context of thinking about children's transport and school travel policy. Problems in the measurement of route data may be drawing attention toward environmental features and/or social factors that may in fact have little bearing on the travel outcomes of interest—if the evidence base is not sound, interventions guided by research may fall flat in achieving their stated objectives. Moreover, much of the school travel research to date has found inconsistent results regarding objectively measured environmental correlates in particular (Wong, Faulkner, and Buliung 2011). Measurement alone does not likely explain all of this difference. It is also very likely that socio-cultural, historical, political, and differences in planning and school travel policies across the series of places where work of this sort has been conducted also explains heterogeneity in research findings.

Conceptually, one would think that the mapped route would have greater validity than the shortest path, as this is the environment children must interact with or overcome while traveling to and from school. However, this may not always be the case, as some parents may have made mistakes drawing the routes. More importantly, parents and children may have an entirely different conceptualization of "neighborhood" or "environment" that does not fit nicely into the sort of objective models, which may assume economically rational behaviors, often used in the literature but that could very well be responsible for the generation of experiences and attitudes influencing transport decisions. Moreover, these constructions or imaginings of "neighborhood" and "environment" could very well differentiate across and within households, and change over time. More research into individual and household environmental perception, acuity and how individuals and households construct the "idea" of their neighborhood is likely going to benefit research designed to identify social and environmental correlates of children's transport.

11.1 Important features related to walking regardless of measurement

This study contributes additional empirical evidence regarding the relationship between the built environment and school travel mode. Distance related to walking for both trips regardless of measurement type. The issue of distance between home and school is twofold. If the distance is too far, a child may be less likely to walk and could spend more time sedentary in a vehicle. Whereas if the distance is too short, even if the student is walking, he or she is unlikely to obtain a significant amount of physical activity. Distance is the most common factor associated with mode of travel, as the distance increases, rates for walking decrease (Schlossberg et al. 2006; Larsen et al. 2009; Larsen, Gilliland, and Hess 2012). If more children are walking to and from school, they may be obtaining a few minutes of activity, but more importantly they are setting healthy habits and will hopefully walk to other destinations as well.

The critical question with regard to distance, however, is not so much the obvious finding that longer distances increase the odds of automobile use, or the completely parochial finding that if you walk a longer distance, you are getting more physical activity. Indeed, the important question with regard to city building, urban design, and planning concerns how distances between people, in this case children, and places, in this case schools, get produced in the first place. What are the structural/institutional/

political/economic and/or social barriers to the production of walkable/bikeable distances? This, in our view, is the more salient question to be asking with regard to distance and school travel. Of course, school travel models must include distance in their specification, but the propensity to report rather trivial conclusions regarding distance effects obfuscates the complexity of the distance issue.

If children had to cross more streets (or intersections) along the mapped route they had lower odds of walking. In relation to the shortest path, major street crossings reported similar results for the to-school trip. This finding makes sense, as crossing more streets could place a child at greater risk of being struck by a motor vehicle. Furthermore, parents may perceive intersection environments as more dangerous and may not allow their child to walk. Overall this study provided some evidence of how street crossings may relate to walking for a variable that commonly has mixed results (Schlossberg et al. 2006; Kerr et al. 2006; Larsen, Gilliland, and Hess 2012).

On the trip home from school, the density of street trees along the route and shortest path significantly related to walking. While a few recent papers examined this feature for children (Larsen et al. 2009; Larsen, Gilliland, and Hess 2012), it remains relatively understudied. This finding demonstrates the importance of street trees and neighborhood aesthetics more generally, as an environmental attribute that appears supportive of active school travel. Many of the older neighborhoods have a much higher density of street trees (mean: 140 trees per kilometer or route) than some of the newer inner-suburban developments (mean: 63 trees per kilometer of route). Tree planting programs are a modifiable way to improve the environment and possibly even encourage or help to improve rates of active travel. Tree planting efforts may be most beneficial when targeting inner-suburban neighborhoods.

Incomplete sidewalks were negatively associated with walking on the trip home from school. Again, much of the previous literature on AST and sidewalks has reported mixed results to date (Boarnet et al. 2005; Fulton et al. 2005; Kerr et al. 2006; Larsen, Gilliland, and Hess 2012). While most neighborhoods in Toronto have a complete network, there were a few areas within our sampled neighborhoods where sidewalks were missing. This finding can easily translate into policy applications related to sidewalk development (no new development should take place without the construction of a complete sidewalk network). School travel itself probably does not provide a sufficient case for sidewalk development, but it appears from these findings that complete sidewalk networks likely facilitate walking.

The child's gender was also an important characteristic regardless of measurement. The odds of walking were nearly two times greater for boys on the trip to school (1.9 for mapped route and 2.2 for shortest path). On the trip home, gender was only significant when the mapped route was examined, where boys once again had an odds ratio of 1.9. The importance of gender is consistent with previous work (Yarlagadda and Srinivasan 2008; Mitra, Buliung, and Roorda 2010; Larsen, Gilliland, and Hess 2012). Overall, the findings related to gender highlight its significance in school travel decisions irrespective of the approach to environmental measurement.

12 Conclusion

This study shed some light on how different methods can produce inconsistent results pertaining to how the environment relates to mode of travel. Differences in findings between the shortest-path and reported mapped-route models highlight a methodological challenge in school travel research; getting the context "right" is no easy task, and making gross assumptions about context and route behavior in childhood transport studies may be producing erroneous evidence and misguided conclusions. Findings from this study highlight the importance of geographical context when examining the environment and health, as results from environmental analysis may contain more uncertainty than originally thought. Although findings from this study may also provide additional evidence, more work should examine how parents and children conceptualize space and place in relation to mobility and transport to obtain a better understanding of how to capture objective and perceived environments.

This study also adds to the current empirical findings related to mode choice and the built environment. Depending on the environmental modeling method applied, different environmental features were significantly related to walking. The fact that many of these features were significant regardless of the measurement highlights the importance of these characteristics. Three common environmental features were missing sidewalks, street trees, and street crossings. The importance of street trees and missing sidewalks were indeed important findings as few studies have examined these variables. Completing sidewalk networks and planting trees near the street may relate to higher walking rates. Furthermore, gender was also important regardless of measurement; boys are more likely to walk to school than girls. While many of these findings have been reported in previous work, this study adds additional evidence while accounting for measurement of the environment. Any improvements to the environment could not only encourage AST but also increase overall rates of walking and physical activity and help to establish healthier travel habits for people of all ages.

Acknowledgements

This research was supported by funding from the Heart and Stroke Foundation and the Canadian Institutes of Health Research (principal investigators, Faulkner and 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.

References

Active Healthy Kids Canada. 2013. Report Card on Physical Activity for Children and Youth. Toronto: Active Healthy Kids Canada.

Black, L. J., and J. Macinko. 2008. Neighborhoods and obesity. *Nutrition Review* 66: 2–20. doi: 10.1111/j.1753-4887.2007.00001.x.

Boarnet, M.G., K. Day, C. Anderson, T. McMillan, and M. Alfonzo. 2005. California's safe routes to school program: Impacts on walking, bicycling, and pedestrian safety. *Journal of the American Planning Association* 71(3): 301–317.

Braza, M., W. Shoemaker, and A. Seeley. 2004. Neighborhood design and rates of walking and biking to elementary school in 34 California communities. *American Journal of Health Promotion* 19: 128–136.

Buliung, R. N., R. Mitra, and G. Faulkner. 2009. Active school transportation in the Greater Toronto Area, Canada: An exploration of trends in space and time (1986–2006). *Preventive Medicine* 48: 507–512. doi: 10.1016/j.ypmed.2009.03.001.

Buliung, R. N., K. Larsen, G. E. J. Faulkner, and M. Stone. 2013. The "Path" not taken: Route discordance in school travel research. *American Journal of Public Health* 103: 1589–1596. doi: 10.2105/AJPH.2012.301172

Buliung, R. N., K. Larsen, G. E. J. Faulkner, P. M. Hess, and L. Rothman. 2015. Driven to School: Social Fears and Traffic Environments. In *The Urban Political Economy and Ecology of Automobility: Driving Cities, Driving Inequality, Driving Politics*, edited by A. Walks. Toronto: Routledge.

City of Toronto. 2010. http://www1.toronto.ca/wps/portal/contentonly?vgnextoid=9acb5f9cd70bb210VgnVCM1000003dd60f89RCRD&vgnextchannel=1a66e03bb8d1e310VgnVCM10000071d60f89RCRD.

Conroy, M. B., N. R. Cook, J. E. Manson, J. E. Buring, and I. M. Lee. 2005. Past physical activity, current physical activity, and the risk of coronary heart disease. *Medicine and Science in Sports and Exercise* 37: 1251–1256.

Chaix, B. 2009. Geographic life environments and coronary heart disease: A literature review. Theoretical contributions, methodological updates, and a research agenda. *Annual Review of Public Health* 30: 81–105. doi: 10.1146/annurev.publhealth.031308.100158.

Cummins, S. 2007. Investigating neighborhood effects on health—Avoiding the local trap. *International Journal of Epidemiology* 36: 355–57.

Diez-Roux, A. V. 1998. Bringing context back into epidemiology: Variables and fallacies in multilevel analysis. *American Journal of Public Health* 88: 216–22.

DiMaggio, C., and G. Li. 2012. Roadway characteristics and pediatric pedestrian injury. *Epidemiologic Reviews* 34: 46–56. doi: 10.1093/epirev/mxr021.

Faulkner, G. E. J., R. N. Buliung, P. K. Flora, and C. Fusco. 2009. Active school transport, physical activity levels and body weight of children and youth: A systematic review. *Preventive Medicine* 48: 3–8. doi: 10.1016/j.ypmed.2008.10.017.

Faulkner, G. E. J., V. Richichi, R. N. Buliung, C. Fusco, and F. Moola. 2010. What's quickest and easiest? Parental decision making about school trip mode. *International Journal of Behavioral Nutrition and Physical Activity* 7: 62. doi: 10.1186/1479-5868-7-62.

Frank, L., J. Kerr, J. Chapman, and J. Sallis. 2007. Urban form relationships with walk trip frequency and distance among youth. *American Journal of Health Promotion* 21. doi: 10.4278/0890-1171-21.4s.305.

Fulton, J. E., J. L. Shisler, M. M. Yore, and C. J. Caspersen. 2005. Active transportation to school: Findings from a national survey. *Research Quarterly for Exercise and Sport* 76(3): 352–357.

Inagami, S., D. A. Cohen, and B. K. Finch. 2007. Nonresidential neighborhood exposures suppress neighborhood effects on self-rated health. *Social Science and Medicine* 65: 1779–91.

Janssen, I., and A. G. LeBlanc. 2010. Systematic review of the health benefits of physical activity and fitness in school-aged children and youth. *International Journal of Behavioral Nutrition and Physical Activity* 7: 40. doi: 10.1186/1479-5868-7-40.

Kerr, J., D. Rosenberg, J. F. Sallis, B. E. Saelens, L. D. Frank, and T. J. Conway. 2006. Active commuting to school: Associations with environment and parental concerns. *Medicine and Science in Sports and Exercise* 38: 787–794.

Kerr, J., L. Frank, J. F. Sallis, and J. Chapman. 2007. Urban form correlates of pedestrian travel in youth: Difference by gender, race-ethnicity and household attributes. *Transportation Research Part D* 12: 177–182. doi: 10.1016/j.trd.2007.01.006.

Kwan, M-P. 2012. The uncertain geographic context problem. *Annals of the Association of American Geographers* 102: 958–968. doi: 10.1080/00045608.2012.687349.

Kwan, M-P. 2009. From place-based to people-based exposure measures. *Social Science and Medicine* 69: 1311–1113. doi: 10.1016/j.socscimed.2009.07.013.

Kwon, S., T. L. Burns, S. M. Levy, and K. F. Janz. 2013. Which contributes more to childhood adiposity-high levels of sedentarism or low levels of moderate-through-vigorous physical activity? The Iowa bone development study. *The Journal of Pediatrics* 3476: 1405–1409. doi: 10.1016/j.jpeds.2012.11.071.

Larouche, R., T. Saunders, G. E. J. Faulkner, R. C. Colley, and M. S. Tremblay. 2012. Associations between active school transport and physical activity, body composition and cardiovascular fitness: A systematic review of 68 studies. *Journal of Physical Activity and Health* 11: 206–227. doi: 10.1123/jpah.2011-0345.

Larsen, K., J. Gilliland, P. M. Hess, P. Tucker, J. Irwin, and M. He. 2009. Identifying influences of physical environments and socio-demographic characteristics on a child's mode of travel to and from school. *American Journal of Public Health* 99: 520–526. doi: 10.2105/AJPH.2008.135319.

Larsen, K., J. Gilliland, and P. M. Hess. 2012. 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* 102: 1–18. doi: 10.1080/00045608.2011.627059.

Larsen, K., R. N. Buliung, and G. E. J. Faulkner. 2013. Safety and school travel: How does the environment along the route relate to safety and mode choice? *Transportation Research Record* 2327: 9–18. doi: 10.3141/2327-02.

Lee, M. C., M. R. Orenstein, and M. C. Richardson. 2008. Systematic review of active commuting to school and children's physical activity and weight. *Journal of Physical Activity and Health* 5: 930–949.

Matthews, S. A. 2008. The salience of neighborhood: Some lessons from sociology. *American Journal of Preventive Medicine* 34: 257–59. doi: 10.1016/j.amepre.2007.12.001.

McDonald, N. C. 2007. Active transportation to school: Trends among US schoolchildren, 1969–2001. *American Journal of Preventive Medicine* 32: 509–516. doi: 10.1016/j.amepre.2007.02.022.

McDonald, N. C., A. L. Brown, L. M. Marchetti, and M. S. Pedroso. 2011. US school travel, 2009: An assessment of trends. *American Journal of Preventive Medicine* 41: 146–151. doi: 10.1016/j.amepre.2011.04.006.

McMillan, T.E. 2007. The relative influence of urban form on a child's travel mode to school. *Transportation Research Part A* 41: 69–79. doi: 10.1016/j.tra.2006.05.011.

Mitra, R., R. N. Buliung, and M. J. Roorda. 2010. The built environment and school travel mode choice in Toronto, Canada. *Transportation Research Record* 2156: 150–159. doi: 10.3141/2156-17.

Morency, C., and M. Demers. 2010. Active transportation as a way to increase physical activity among children. *Child: Care, Health and Development* 36: 421–427. doi: 10.1111/j.1365-2214.2009.01024.x.

Murray, L. 2009. Making the journey to school: The gendered and generational aspects of risk in constructing everyday mobility. *Health, Risk and Society* 11: 471–486. doi: 10.1080/13698570903183889.

National Highway Traffic Safety Administration (NHTSA). 2003. *Vehicle Weight, Fatality Risk and Crash Compatibility of Passenger Cars and Light Trucks.* Springfield, VA: US Department of Transportation.

Panter, J., A. Jones, E. van Sluijs, and S. Griffin. 2011. The influence of distance to school on the associations between active commuting and physical activity. *Pediatric Exercise Science* 23: 72-86.

Panter, J. R., A. P. Jones, E. M. F. van Sluijs, and S. J. Griffin. 2010. Neighborhood, route, and school environments and children's active commuting. *American Journal of Preventive Medicine* 38: 268–278. doi: 10.1016/j.amepre.2009.10.040.

Panter, J. R., A. P. Jones, E. M. F. van Sluijs, and S. J. Griffin. 2010b. Attitudes, social support and environmental perceptions as predictors of active commuting behavior in school children. *Journal of Epidemiology and Community Health* 64: 41–48. doi: 10.1136/jech.2009.086918.

Sallis, J. F., N. Owne, and E. B. Fisher. Ecological models of health behavior. 2008. In *Health Behavior and Health Education: Theory, Research, and Practice*, edited by K. Glanz, B. K. Rimer, and K. Viswanath. San Francisco: John Wiley and Sons.

Schlossberg, M., J. Greene, P. P. Phillips, B. Johnson, and B. Parker. 2006. School trips: Effects of urban form and distance on travel mode. *Journal of the American Planning Association* 72: 337-346. doi: 10.1080/01944360608976755.

Sirard, J., and M. Slater. 2008. Walking and bicycling to school: A review. *American Journal of Lifestyle Medicine* 2: 372–396. doi: 10.1177/1559827608320127.

Telama, R., X. Yang, J. Viikari, I. Valimaki, O. Wanne, and O. Raitakari. 2005. Physical activity from childhood to adulthood: A 21-year tracking study. *American Journal of Preventive Medicine* 28: 267–273. doi: http://dx.doi.org/10.1016/j.amepre.2004.12.003.

Timperio, A., K. Ball, J. Salmon, R. Roberts, B. Giles-Corti, D. Simmons, L. A. Baur, and C. Crawford. 2006. Personal, family, social, and environmental correlates of active commuting to school. *American Journal of Preventive Medicine* 30: 45–51. doi: http://dx.doi.org/10.1016/j.amepre.2005.08.047.

Trost, S. G., L. M. Kerr, D. S. Ward, and R. R. Pate. 2001. Physical activity and determinants of physical activity in obese and non-obese children. *International Journal of Obesity* 25: 822–829.

van Loon, J., and L. Frank. 2011. Urban form relationships with youth physical activity implications for research and practice. *Journal of Planning Literature* 26: 280–308. doi: 10.1177/0885412211400978.

Vovsha, P., and E. Petersen. 2005. Escorting children to school: A statistical analysis and applied modeling approach. *Transportation Research Record* 1898: 87–97. doi: 10.3141/1921-15.

Wilks, D., H. Besson, A. Lindroos, and U. Ekelund. 2010. Objectively measured physical activity and obesity prevention in children, adolescents and adults: A systematic review of prospective studies. *Obesity Reviews* 12: 119–29. doi: 10.1111/j.1467-789X.2010.00775.x.

Wong B. Y., G. Faulkner, and R. Buliung. 2011. GIS measured environmental correlates of active school transport: A systematic review of 14 studies. *International Journal of Behavioral Nutrition and Physical Activity* 8: 39. doi: 10.1186/1479-5868-8-39.

Yarlagadda, A. K., and S. Srinivasan. 2008. Modeling children's school travel mode and parental escort decisions. *Transportation* 35: 201–218. doi: 10.1007/s11116-007-9144-6.

Zegeer, C. V., and M. Bushell. 2012. Pedestrian crash trends and potential counter measures from around the world. *Accident Analysis and Prevention* 44: 3–11. doi: 10.1016/j.aap.2010.12.007.