

Urban Form, Children's Active Travel to/from School, and Travel related Physical Activity

メタデータ	言語: English 出版者: 公開日: 2020-03-05 キーワード: 作成者: Lee, Jong Seon メールアドレス: 所属:
URL	https://doi.org/10.24517/00057204

This work is licensed under a Creative Commons Attribution-NonCommercial-ShareAlike 3.0 International License.



Urban Form, Children's Active Travel to/from School, and Travel related Physical Activity

Jong Seon Lee^{1*}

1 Korean Intellectual Property Office

* Corresponding Author, Email: jongslee@korea.kr

Received: Oct 12, 2017; Accepted: Feb 2, 2019

Key words: New Urbanism, Urban Form, Physical Activity, Active Travel, Accelerometer, GPS (global positioning system)

Abstract: Children's active travel (AT—i.e., walking, bicycling) has declined substantially, especially for independent active travel (IAT). An increasing number of studies have examined walking behaviour of adults to test the new urbanist hypothesis that design features should support pedestrian activity. More neighbourhood adult walking has been reported in new urbanist communities than in conventional suburban neighbourhoods. However, study of children's AT in new urbanist settings is under-represented. This study investigates the association between neighbourhood design and children's active school travel (AST) in conventional and new urbanist neighbourhoods. Three types of data collection methods were used: survey, travel diary, and devices (accelerometers and GPS units). 4-5th graders, 367 children in conventional suburban and new urbanist neighbourhoods, participated in the children's survey. Among 367, 60 wore accelerometers and GPS units for seven consecutive days and recorded a travel diary. Built environment (BE) variables including distance to school, children's population density, mixed land use, street density, intersection and sidewalk density, and physical activity (PA) locations around the home were measured within a quarter mile buffer of each participant's home in ArcGIS. Analyses of a further 254 students living within 2 miles from school with opportunities for walking were also conducted. T-test confirmed all BE variables were significantly different between conventional and new urbanist neighbourhoods. New urbanist children engaged in twice the number of days of walking and 5-7 times more days of biking compared to children in conventional neighbourhoods. Maps were interpreted from the perspective of (1) sidewalk network, (2) traffic features, and (3) PA locations around the routes to schools. Results finally suggest the need for further tests of new urbanist design principles in relation to children's AT to support development of neighbourhood design policies and interventions that may provide health promotion benefits to children.

1. INTRODUCTION

Children's active travel (AT) (i.e., walking, bicycling) has declined substantially. Especially in the case of active school travel (AST), the decrease is significant for children in the United States (U.S.) ([McDonald, 2007](#)), particularly for independent active travel (IAT). Degrees of freedom for children to move around independently have diminished during recent decades ([Gaster, 1992](#)). In a similar vein, walking or cycling to or from school has consistently declined ([Sirard & Slater, 2008](#)). Autocentric

environments have become one of the most important factors influencing children's daily physical activity (PA). In 1969, approximately half of all U.S. school children walked or bicycled to or from school. Among children living within 1 mile of school, 87% of those walked or cycled ([US Department of Transportation \(DOT\), 1972](#)). In 2000, fewer than 15% of children and adolescents used active travel to or from school ([US Environmental Protection Agency \(EPA\), 2003](#)).

Recent policies and programs have targeted the built environment as a primary factor in discouraging children's AT. An increasing amount of literature examines how the built environment (BE) supports or restricts children's AT. In the domain of community design, studies have begun to examine walking behaviour in association with new urbanist design principles that hypothetically provide supportive design features related to pedestrian activity ([Rodriguez, Khattak, & Evenson, 2006](#); [Brown, Khattak, & Rodriguez, 2008](#)). These principles have been termed the 5D framework, including *Distance* of home to school, child *Density*, land use *Diversity*, pedestrian friendly *Design* and *Destination* of PA facilities such as parks. When homes are located on small lots near amenities, the resulting compact development and proximity make walking trips more feasible. Mixed use increases proximity (shorter trip distances), and thereby supports active travel. Streets with well-connected grid designs provide more direct and pleasant AT. Recent investigations comparing new urbanist neighbourhoods with conventional suburbs have focused on adult health outcomes, including BMI and walking behaviours ([Rodriguez, Khattak, & Evenson, 2006](#); [Brown, Khattak, & Rodriguez, 2008](#)). To the authors' knowledge, only one study ([Stevens & Brown, 2011](#)) examines children's AT, in this case using accelerometer-measured PA to compare outcomes from a new urbanist community, a mixed community, and a less walkable community. The current study compares the BE and AST patterns by neighbourhood type (conventional vs. new urbanist). Empirical evidence on neighbourhood design is essential to inform design and policy interventions.

2. LITERATURE REVIEW

2.1 Conceptualization of Independent Active Travel

In middle childhood, children typically venture away from home independently to explore the physical and cultural environment of their community. This involves developmentally appropriate risks and allows the child to overcome challenges to discovering and learning ([Natural Learning Initiative \(NLI\), 2010](#)). The term 'independent mobility' has been widely used in previous literature, however, in this study, 'independent active travel' will be used to focus on children's non-motorized mobility.

In the study of independent active travel, three types of definitions and operationalization have been applied ([Kytta, 2004](#)). In the earliest work, independent active travel was studied by measuring the territorial range. Territorial range is defined as the geographical distance from children's homes to places where children are allowed to wander for playing and socializing ([Hart, 1979](#); [van Vliet, 1983](#); [Moore, 1986](#)). Secondly, it was conceptualized as a license to move around independently. The degree of an active travel license refers to sets of rules defined by parents concerning, for example, permission to cross roads or to ride a bicycle independently ([Hillman, Adams, & Whitelegg, 1990](#); [O'Brien et al., 2000](#)). Studies using

the third definition have attempted to measure the level of children's actual active travel such as route or destination within a certain period of time. This can be done, for example, by using GPS and/or travel diaries ([Mavoa et al., 2011](#); [Rodriguez et al., 2012](#)).

Territorial range encompasses a child's play and leisure places and the pathways connecting them ([Moore & Young, 1978](#)). It has three levels of involvement: habitual, frequented, and occasional ([Moore, 1986](#)). Habitual range is continuous and highly accessible space for daily use around the child's home. Frequented range is less accessible than habitual range and bounded by physical restraints such as busy roads and also parental restrictions. It can be expanded with age, the use of bicycles, traffic-free routes and the presence of older children. Occasional range is a highly variable extension of frequented range and is dependent on the degree of freedom and training offered by parents, and the availability of traveling companions. Since the present study focuses on the physical environment of the neighbourhood, it deals, for the most part, with the habitual range.

Parents grant or withhold license. Parents who know that children are vulnerable to traffic hazards increase their restriction which decreases children's active travel. Lenient license is given when a parent believes that the child is safe. However, children should not be seen as passively obeying the active travel restrictions of their parents. They can become skilful negotiators for greater extension of their license to move around. This is one reason it is important to distinguish between actual active travel and the degree of an active travel license ([Kytta, 2004](#)). The socio-demographic of children affects parents' decisions about children's travel and outside independent play, which varies by gender, with boys having more freedom at an earlier age than girls ([Moore, 1986](#); [van Vliet, 1983](#)). For the purposes of this paper, parental license was defined as parental approval to engage in independent forms of PA and AT.

2.2 Active School Travel

Nationally, initiatives such as Safe Routes to School (SRTS), the Walking School Bus (WSB), or the Walk to School (WTS) program have been implemented to increase children's walking and cycling to school with some success ([Chillon et al., 2011](#)). The federal Safe Routes to School (SRTS) program is intended to make walking and cycling to and from school safer and more accessible for children in order to enhance their health and improve traffic and air quality near the school.

SRTS programs are designed to increase the percentage of students who walk or cycle to school by addressing barriers through the "four Es" (engineering, enforcement, education, and encouragement) ([Centers for Disease Control and Prevention \(CDC\), 2005](#)). In the encouragement approach, schools arrange for children to meet within a mile of school and proceed to school in "walking school buses," in which an adult "caboose" escorts children walking together. This strategy may extend the barrier of distance and reduce the fear of crime. From an engineering approach, programs install crossing signals, and in an enforcement approach, speed limits are vigorously enforced to address the traffic barrier. From the education approach, programs teach children pedestrian skills in the classroom.

The "Four Es" approach has achieved the desired results. For example, one comprehensive SRTS program in Marin County, California, that uses all of the "four Es" resulted in a 64% increase in walking and a 114% increase

in bicycling by the second year of their program ([Staunton, Hubsmith, & Kallins, 2003](#)). The SRTS program in Tempe, Arizona, has made engineering improvements to enhance pedestrian safety and has promoted walking through an annual Walk to School Day. It has contributed to a decrease in automobile traffic near elementary schools during morning and afternoon rush hours. Implementing SRTS programs and removing or improving barriers for walking may contribute significantly to the increase of children's outdoor activity.

2.3 Built Environment and Active School Travel

Children's active travel has been widely investigated regarding correlates of demographic, family, school, social and physical environments. Several systematic meta-analyses reviewed studies of the impact of BE on AST ([Davison, Werder, & Lawson, 2008](#); [Panter, Jones, & van Sluijs, 2008](#); [Sirard & Slater, 2008](#); [Pont et al., 2009](#)). Distance, walking, cycling path, and few hills are found positively related to AST.

Recently, Wong et al.'s meta-analysis ([2011](#)) in the systematic review of 16 studies showed GIS measured environmental correlates of active school travel. Only distance was consistently found to be negatively associated with AST. Consistent findings of positive or negative associations were not found for residential density, land use mix, or connectivity. This inconsistency may be attributed to the fact that some inherent methodological challenges exist in this type of research. Some important BE features may not be assessed, the relationship between the BE and AST may be different in different cities, and AST may be moderated by other factors, such as demographic or parental perception ([Wong, Faulkner, & Buliung, 2011](#)). The effect of distance as a strong barrier corresponds with parents' perception. A report ([Centers for Disease Control and Prevention \(CDC\), 2005](#)) examining data from the 2004 Consumer Styles Survey described what parents report as barriers to their children aged 5-18 years walking to or from school. Among barriers, distance to school was the primary barrier, followed by traffic safety. There is the need for researchers to make a distinction between to school travel, and from school travel ([Wong, Faulkner, & Buliung, 2011](#)).

Some studies examined differences in children's independent active travel in urban and rural neighbourhoods. Previous findings about density have been inconsistent. Some studies suggest that children in lower-density environments enjoy higher degrees of license than do children in high-density city environments ([O'Brien et al., 2000](#); [Kytta, 1997](#)). On the other hand, some studies show that there is no greater potential for rural children to move around independently compared to urban children ([Matthews, Limb, & Taylor, 2000](#)).

2.4 Built Environment Measures in Active Travel Research

Related to AST, there are a number of ways to measure each BE variable.

Distance: Many studies ([McDonald, 2007](#); [Larsen et al., 2009](#)) measure distance from home to school. The study used network distance which is the shortest path to a participant's school along the circulation system using the Network Analyst tool in GIS. This was negatively associated with walking

or biking to school. In McDonald's study, distance to school was measured differently. With geocoded home and school location, crow-fly distance was measured. Then, distance was defined as a modified crow-fly distance assuming children followed a gridded street network, i.e. distance is the sum of the x and y vectors between points A and B. As a result, for trips of less than 1.6 km, distance is strongly negatively associated with the trip, but once children face trip distances of more than a mile, the distance is irrelevant.

Density: [McDonald \(2007\)](#) used dwelling density and employment density. Dwelling density is defined as dwelling units per km² and employment density means employees per km². [Larsen et al. \(2009\)](#) differentiated dwelling density and residential density. Residential density is defined as the ratio of total residents to the residential area. A residential index measures "whether an area is predominantly residential or commercial" and defined as housing units divided by total employment and housing units. On the other hand, [Ewing, Schroeer, and Greene \(2004\)](#) used overall density which is calculated by "(residents + jobs)/area," with which [McDonald \(2007\)](#) found a significantly positive relationship between dwelling density and children's trips of more than 1.6km, but not for shorter trips. In Larsen et al.'s study ([2009](#)), residential density is significantly associated with active commuting to home, not to school. [Ewing, Schroeer, and Greene \(2004\)](#) does not show a significant relationship between BE and AST.

Diversity (Land Use Mix): Land use mix was measured using entropy (E), defined as the degree of mixing across land-use categories within a neighbourhood. The mean entropy ranges between 0 (homogeneity, wherein all land uses are of a single type) and 1 (heterogeneity, wherein developed area is evenly distributed among all land use categories) ([Cervero & Kockelman, 1997](#)). As part of diversity, [Ewing, Schroeer, and Greene \(2004\)](#) measured a commercial floor area ratio (FAR) for each parcel. FAR shows as the ratio of a parcel's commercial floor area to the parcel's land area dedicated to commercial uses. Among three studies, only Larsen et al. found a positive relationship between land use mix and AST. Regarding diversity, [Ewing, Schroeer, and Greene \(2004\)](#) mentioned that for the calculation of FAR, only pedestrian-oriented commercial uses were included—specifically, retail uses; including finance, insurance, real estate offices, etc. The pedestrian-oriented commercial is worthy of consideration, however, the study does not specify the criteria of pedestrian-oriented commercial.

Design- connectivity-intersection/ street density: A previous study ([Larsen et al., 2009](#)) defined it as the number of intersections per square mile in a neighbourhood. The other ([McDonald, 2007](#)) used several measures such as the number of intersections per km² and the percentage of 1, 3, 4, and 5-way intersections within an 800 m buffer around the home. Neither study found an association between intersection density and AST. [Ewing, Schroeer, and Greene \(2004\)](#) used street density which is centreline street miles per square mile. This variable measures street network density, including local streets as well as arterials and collectors.

Design- sidewalk/ bike lane: [Ewing, Schroeer, and Greene \(2004\)](#) examined detailed variables in terms of sidewalk and bike land; proportion of street miles with sidewalks; proportion of street miles with bike lanes or paved shoulders; and average sidewalk width. These variables were available only for arterial and collector streets. No associations were found between densities of bike lanes and sidewalks, average sidewalk width and

AST. [Larsen et al. \(2009\)](#) examined sidewalk length, but they did not find any association between sidewalk completeness and AST.

Design- street trees: A previous study ([Larsen et al., 2009](#)) measured trees along roads within 5 meters from road edges using data from Street Tree Inventory. Another study ([Ewing, Schroeer, & Greene, 2004](#)) measured the proportion of street miles to street trees using the county level pedestrian service database. While [Larsen et al. \(2009\)](#) found an association, [Ewing, Schroeer, and Greene \(2004\)](#) found no association with AST.

The active travel literature has been limited to school travel only. In school travel, “being independent” which has an influence on children’s PA level and developmental benefits, has not been properly addressed. This study examines a children’s AST with diverse spectra by modes, destinations, and independence across neighbourhood types.

3. METHODS

3.1 Research Design and Site Selection

North Carolina, Chapel Hill-Carrboro City Schools (CHCCS) elementary schools, local government, a national program, Go! Chapel Hill, and Active Living by Design collaborated to encourage the safe route to school (SRTS) program. Many Chapel Hill residents are health-conscious and proactive regarding health and physical activity, thus encouraging partnership for SRTS. Reflecting this background, Chapel Hill sites participating in the SRTS program had the advantage of community awareness of students engaged in walking programs and related activities.

Participants were recruited through four elementary schools participating in the SRTS program. The neighbourhoods around the four selected schools had a similar 6-11 year old population and socio-economic status (U.S. Census block data). Schools 1 and 2 were located in conventional suburban neighbourhoods, and schools 3 and 4 were located in new urbanist neighbourhoods. The attendance school zones of schools 3 and 4 also include residences outside of new urbanist sites; thus, those participants were classified as conventional suburban residents. Each participant’s neighbourhood was defined as a quarter mile crow-fly buffer around each participant’s home.

3.2 Participants

4th to 5th grade (9-11 year-old) children are at the stage of development of increasing independence and are relatively advanced in their spatial-cognitive skills. According to ([Piaget & Inhelder, 1963](#)) AT is crucial for the development of cognitive representations of the environment. Exploratory activities are especially important for children to learn to walk around the neighbourhood with a coordinated system of reference. The period of approximately 10–12 years of age often marks a steep decline in physical activity and coincides with the transition from primary to secondary school. This is also a period when parental license for children to engage in physical activity without adult supervision increases ([Jago et al., 2009](#)).

3.3 Children's Survey

4th to 5th grade elementary school children ($N=367$) in four schools participated in a group-administered survey at the schools. During the information session, questionnaires were administered in group settings, and each respondent was asked to complete it while in the room. If the respondents were unclear about the meaning of a question, they asked the researcher or teachers for clarification.

AST frequency and modes were developed from the "Active Where" parent children survey ([Joe, Carlson, & Sallis, 2018](#)). Two sections include school travel mode and independent active school travel questions, as follows. First: "In a normal school week, how many days do you go to / from school in the following ways?" The options are walk, bike, go by car, and go by bus, and participants are asked to circle one row for TO school and one for FROM school. Second: "If you walk or bike to/from school, how many days do you walk or bike without an adult?"

3.4 Built Environment Variables

To account for how neighbourhoods' characteristics around homes are associated with children's AT behaviours, BE variables around each participant's home were measured within the quarter mile crow-fly buffer. In this study, BE variables were framed within a modified 5D model ([Cervero & Kockelman, 1997](#)). Except for the distance to school, all variables were measured within the home neighbourhood BE, derived using ArcGIS 10.1 (Environmental Systems Research Institute Inc., Redlands, CA).

The 5Ds were: *Distance* from each participant's home to school, estimated as the shortest route possible along a road network measured by Network Analyst 10.1 in ArcGIS. *Density* of child population measured as the number of 6-11 year old children (2010 U.S. census block data). When a buffer around a participant's home was not fully contained within a census block polygon, the data were assigned in direct proportion to the area of the polygon contained within the buffer. *Diversity* of mixed land uses within the neighbourhood and was coded using a binary variable equalling 1 if the neighbourhood had at least one parcel (entirely or partially) with a retail, institutional or office land use code designation, and 0 otherwise. *Design* included connectivity, which comprised length of road, number of intersections, and sidewalk density within the buffer. *Destination* measured PA facilities such as parks, greenway, trails, stream, pond, sports field, YMCA, school, shop, indoor sports facilities (martial arts, dance), cemetery, and bike lane within the quarter mile buffer.

3.5 Accelerometry

Physical activity was measured objectively using an accelerometer (Actigraph, GT1M), which is a small ($38 \times 37 \times 18$ mm) and lightweight device. An Actigraph GT1M measures single-plane vertical activity data as well as step counts and horizontal plane data. Activity meters are set to record the data in 30 second epochs. The instrument has been shown to be valid and reliable for both children and adolescents ([Cain & Geremia, 2012](#)). Using accelerometers to measure children's physical activity and/or directly observed activity removes the possibility of response bias, particularly among children.

Devices were attached to a custom-built elastic belt which is fastened around the waist and positioned over the right hipbone. According to Pate et al. (2002), six valid days' wearing time is recommended, including one weekend. In this study, PA data is collected for seven consecutive days.

After seven days of data collection, activity data was downloaded, validated and processed using Actilife 6 software. Participants' age, gender, reported height, and weight were entered in the data set. In the screening process, it was determined if there is enough wearing time in the file. Non-wear time was defined as >100 consecutive minutes of 0 counts. The data were required to have at least five valid days for each meter worn. A valid day was defined as a day containing at least 10 valid hours. To understand the PA intensity, Freedson's cut point for children (2005) which was measured in 60 second epochs is used, and it is halved since the data is measured in 30 second epochs (Table 1). After the screening process, valid data is used for advanced analysis.

A bout of moderate to vigorous physical activity (MVPA) is defined as 10 or more continuous and consecutive minutes of PA at or exceeding the defined threshold values. Each bout has a 30% tolerance for activity level not meeting the threshold values. For example, in a 10 minute bout, 3 minutes could be under the threshold level. The bout has been considered as an important variable in energy expenditure as research reveals even a short bout is beneficial for health considering children's intermittent movement (U.S. Department of Health and Human Services (HHS), 2008). For the data of accelerometers and GPS units, considering the compliance rate of children (Cain & Geremia, 2012), it is expected that 25% of data are lost due to non-wear, incorrect placement, and loss of equipment. (Cain et al., 2013).

Table 1. Physical Activity Intensity Cut Point

Cut point: Freedson, Pober, and Janz (2005)		(per 30 sec)	
Sedentary	0	-	74
Light	75	-	249
Moderate	250	-	1999
Vigorous	2000	-	3799
Very Vigorous	3800	-	∞

3.6 GPS units

Children's mobility was measured using GPS units (Qstarz Travel Recorder BT-Q1000X), whose dimension is 72.2×46.5×20mm. Devices were attached to a custom-built elastic belt, fastened around the waist and positioned over the right hipbone with an activity meter. The unit recorded date, time, longitude, latitude, altitude, speed, distance, dilution of precision (DOP) and satellite information. GPS units were configured to record data every 30 seconds using QTravel v1.45 software. Several studies showed that Qstarz Travel Recorder has relatively high accuracy and good inter-unit reliability. The GPS alarm was turned off. The modes' switch which controls on/off, Log and Nav mode was removed in order to prevent participants from turning off the units accidentally. Prior to delivery, GPS units were turned on by the researcher. After seven days of data collection,

GPS data was downloaded using QTravel v1.45 software, which produced .csv and .kml (Google earth format) data files.

3.7 Merging of Physical Activity and Active Travel Data

Each participant's accelerometer data and the corresponding GPS data were merged according to date and time information from each unit, so that each GPS point had a corresponding accelerometer count. For the merging process, Actilife software was used for the convenience of use. GPS points without accelerometer data and accelerometer minutes without GPS data are excluded. Thus, each GPS point contains information of PA intensity associated with its accelerometer count. Additionally, Google Street View photos were used to examine the environments around the actual routes to/from schools.

3.8 Travel Diary

Sixty participants were provided with a travel diary form to complete for seven days (Figure 1). The travel diary form was used to verify and understand the context of device participants' activities. They were asked to complete a log of dates and times when they wore the devices, and when they took them off for more than 5 minutes. In terms of active travel, participants are also asked to log time, destination, mode of travel and accompaniment of travel. This will be useful when screening data and helps with participants' compliance by serving as a reminder. In addition, it was helpful determining being independent or not during their activity.

3.9 Analysis

Descriptive statistics were calculated for days of walking/ biking for the entire population. T-tests for BE was performed to examine the possible differences between neighbourhood types. The sub-population of participants living in a 2 mile-buffer with the opportunity to walk was selected. T-tests for AST were performed to examine the possible differences between neighbourhood types.

4. RESULTS

4.1 Built Environment and Individual Characteristics, and Active School Travel

Table 2 presents descriptive statistics of BE, individual and household, and PA variables. One third of participants (30.8%) lived in new urbanist neighbourhoods. Mean distance to school from home was 1.71 miles. Mean population of children was 4.34 per quarter mile buffer. Only 27% of participants lived in mixed-use neighbourhoods.

Mean street length in a quarter mile buffer was 16.3 mile. Mean number of intersections in a quarter mile buffer was 34. Sidewalk density was defined to include not only sidewalk but also paved space from the sidewalk to the front porch; the ratio was 1.03, larger than one.

Almost 50% of participants were 10 years old ($M=10.16$, $SD=0.71$). Proportions of male and female students were similar. Proportions of white

and non-white students were similar. Almost 50% of participants reported having two family motor vehicles ($M=2.05$, $SD=0.76$). The mean of BMI was 19.1 ($SD=3.79$). Two thirds of the students (67.8%) reported having parental permission to go out on their own.

Table 2. Descriptive Statistics of Built Environment and Individual Characteristics

	N	Percent	Mean	SD
BE characteristics (N=367)				
Neighbourhood				
0=Conventional	254	69.2		
1=New Urbanist	113	30.8		
DistToSchool	367		1.71	1.76
PopulationChildren	367		4.34	2.87
Diversity			0.27	0.44
0=No mixed use	269	73.3		
1=Mixed use	98	26.7		
StreetLength	367		16.34	16.71
Intersection	367		33.91	25.93
Sidewalk proportion	367		1.03	1.06
PAlocation	367		1.26	0.81
Individual Characteristics (N=367)				
Age			10.16	0.71
9 years old	67	18.3		
10 years old	174	47.4		
11 years old	126	34.3		
Gender				
Male	186	50.7		
Female	181	49.3		
Ethnicity_white				
Non-white	165	45.0		
White	202	55.0		
MotorVehicle				
0	8	2.2		
1	74	20.2		
2	177	48.2		
3 and above	108	29.4		
BMI	367		19.11	3.79

4.2 Difference of Built Environment Variables by Neighbourhood Type

T-test indicated all BE variables (distance to school, children's population, mixed land use, street length, # of intersection, sidewalk length and PA locations) were confirmed to be significantly different between conventional suburban and new urbanist neighbourhoods (Table 3).

According to the design principles of new urbanist, new urbanist neighbourhoods in the current study provided more walkable environments; distance to school was significantly shorter ($t=10.1$, $df=365$, $p=.000$); number of mixed use was higher ($t=-7.0$, $df=166$, $p=.000$); street was longer ($t=-22.6$, $df=134$, $p=.000$); number of intersections was higher ($t=-17.6$, $df=135$, $p=.000$); sidewalk was longer ($t=-19.2$, $df=114$, $p=.000$); the proportion of sidewalk to street was higher ($t=-18.6$, $df=139$, $p=.000$); and there were more PA locations ($t=-13.7$, $df=364$, $p=.017$). Against the new urbanist design principles, the children’s population density was higher in conventional neighbourhoods ($t=2.4$, $df=364$, $p=.017$). This may be attributed to the housing building types. Almost all new urbanist participants lived in single-family units (only two participants lived in multi-family units comprised of apartments or condominiums). Many conventional neighbourhood participants lived in apartments, which results in higher population density.

Table 3. T-test of BE variables by Neighbourhood Type

	Conventional		New Urbanist		t	df	p
	M	SD	M	SD			
Distance to School	2.16	1.88	0.72	0.86	10.1	365	.000
Population Children	4.52	3.27	3.92	1.55	2.4	364	.017
Diversity	0.15	0.36	0.52	0.50	-7.0	166	.000
Street Length	7.02	6.25	37.28	13.59	-22.6	134	.000
Intersection	20.72	11.67	63.54	24.71	-17.6	135	.000
Sidewalk Density	0.43	0.44	2.01	0.85	-18.6	139	.000
PA Location	0.94	0.64	1.97	0.67	-13.7	206	.000

4.3 Differences in Active School Travel by Neighbourhood Type

Distribution of distance to school showed that after 1 mile from home, the number of students gradually decreased (Figure 1). Further analysis included only the students living within 2 miles from school who had opportunities for walking ($n=254$).

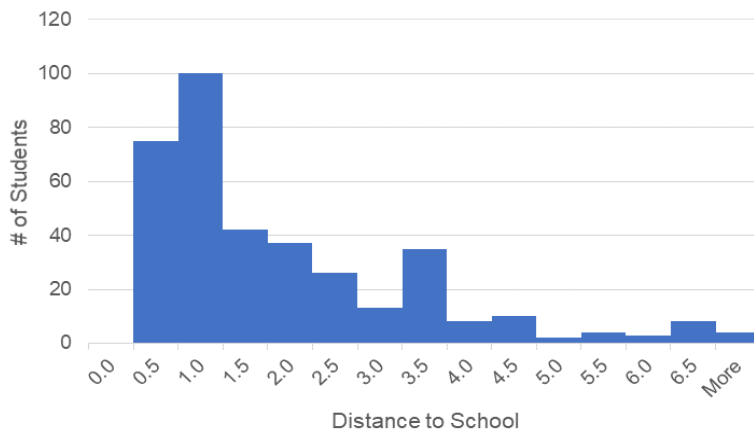


Figure 1. Distribution of Distance to School (mile)

For these 254 students, to understand the association with the built environment, a t-test of AST (days of walking/ biking) was compared with conventional and new urbanist neighbourhood types (Table 4). Since predicting variables were ratios, t-test was used. In days of walking and biking to/from school, new urbanist participants had a higher number of walking and biking days. New urbanist participants had approximately two times more days of walking, and approximately 5-7 times more days of biking. In days of walking and biking to/from school without an adult, new urbanist participants had a higher number of walking and biking days as well.

In both conventional and new urbanist neighbourhoods, the number of walking/biking days to school was lower than days from school. Generally, children and families had busier schedules in the morning, so fewer children walked in the morning than after school. It is noticeable that the difference between to and from school is larger in new urbanist neighbourhood than conventional neighbourhood types. This may indicate that more free time and increased walkable space affords conditions where children are more likely to be engaged in walking/ biking to/from school.

Table 4. T-test of days of AST by Destination, Mode and Neighbourhood Type

		Conventional		New Urbanist		t	df	p
		M	SD	M	SD			
Days to School	Walk	1.10	.257	1.78	.258	-2.7	252	.008
	Bike	.25	.189	1.49	.206	-2.7	252	.008
Days from School	Walk	1.23	.263	2.36	.265	-4.3	225	.000
	Bike	.26	.190	1.45	.207	-5.7	146	.000
Days TO School without an Adult	Walk	.71	.234	1.52	.241	-3.4	204	.001
	Bike	.31	.195	1.33	.210	-4.8	157	.000
Days FROM School without an Adult	Walk	.74	.246	2.28	.256	-6.0	190	.000
	Bike	.30	.196	1.35	.212	-5.0	152	.000

Note: Conventional: N=144, New Urbanist: N=110

4.4 AST Maps – School Travel Related Physical Activity

The purpose of the analysis is to describe where participants were active during school travel and how BE characteristics in conventional suburban and New Urbanist neighbourhoods support the activities. Using data from accelerometer and GPS, 60 participants' AST with PA intensity was mapped

to qualitatively describe their AST within BE around home, school and route. Few quantitative studies using GIS have examined the BE along the routes to school; furthermore, those used network distance from GIS not the actual routes where participants travelled ([Wong, Faulkner, & Buliung, 2011](#)).

In new urbanist neighbourhoods, home, trails, parks, and school location are well integrated. In addition, at the intersection of streets and trails, raised crosswalks are provided, which support participants' active travel especially for biking (Figure 2). Around schools, signalized crosswalks and signage about crossing and speed limit support participants' safe crossing.

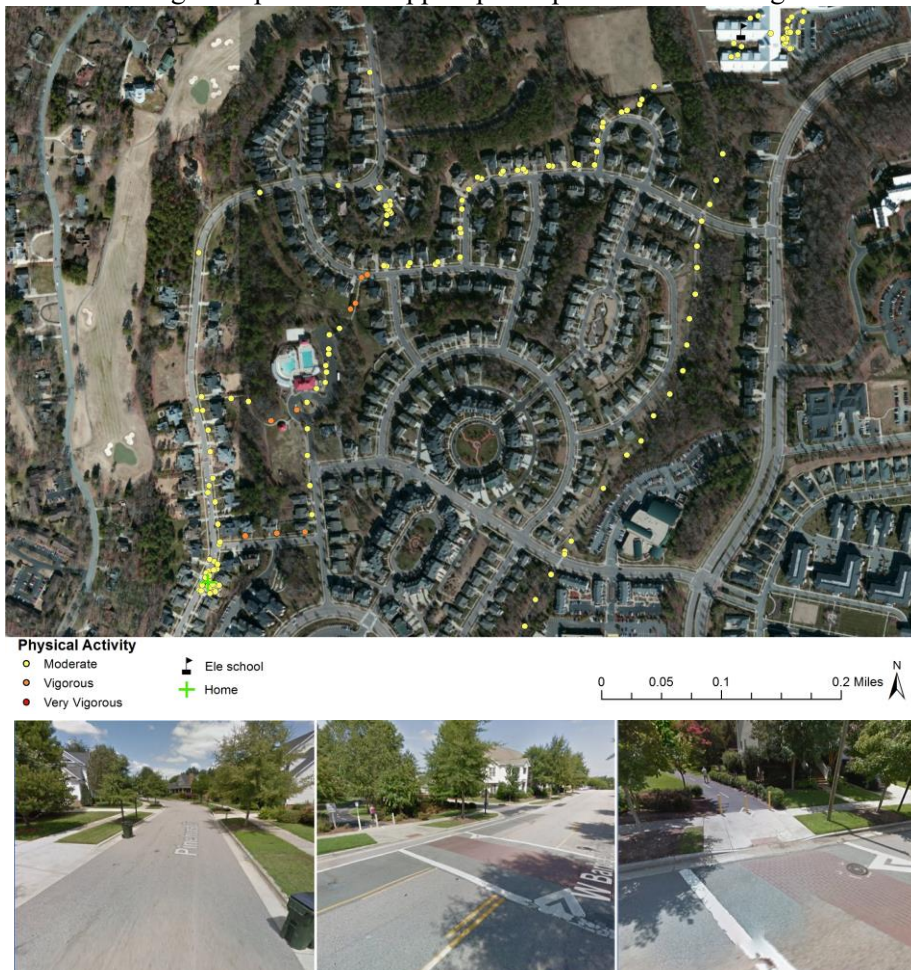


Figure 2. One girl's biking to/from school in a new urbanist neighbourhood. GPS connection may be lost in the woods area near school.

PA locations around routes to/from school make school travel more active. During AST, for some participants visits to the woods, ponds and shops near routes to school were found. Especially in new urbanist neighbourhoods, children were active in open space near shops, woods, ponds and parks when they were returning home from school, during which they tended to have more time to walk and wander around.



Figure 3. One girl school of the new urbanist area had to be driven to school because of no connectivity

5. DISCUSSION

5.1 Built Environment Characteristics

Significant differences were discovered in neighbourhood form and active school travel (AST) between conventional and new urbanist neighbourhood types. Overall, the new urbanist neighbourhood appears to better support a pedestrian friendly school travel environment with shorter distance, increased street connectivity, and positive sidewalk networks. Two previous studies reported higher PA of adults in new urbanist neighbourhoods ([Rodriguez, Khattak, & Evenson, 2006](#); [Brown, Khattak, & Rodriguez, 2008](#)). One study indicated that walkability of a community related to more MVPA minutes of children during the half hour before and after school ([Stevens & Brown, 2011](#)).

From school travel provided valuable opportunities for children's PA considering their busy schedule. The difference in the number of children between *to school* and *from school* was larger in the new urbanist neighbourhood. This may indicate that with more free time and walkable space, children are more likely to be engaged in AST. One study of temporal active school travel patterns ([Mitra, Buliung, & Faulkner, 2010](#)) found that more BE variables were associated with walking in the morning than the afternoon. Due to parental/caregivers' schedules, working parents may not have time to pick up their children. This may lead to the mode shift from passive to active travel ([Wong et al., 2011](#)). For child pedestrians, routes to/from school using minor roads with less traffic volume and lower speed limits tend to be chosen ([Duncan & Mummery, 2007](#)).

5.2 Walking and Biking by Neighbourhood Type

Neighbourhood type was associated with both walking and biking. To the author's knowledge, only one study ([Stevens & Brown, 2011](#)) examined the association of children's accelerometer-measured PA in new urbanism community design in (1) a new urbanist community, (2) a mixed community, and (3) a less walkable community. The results indicated that walkability of a community related to more MVPA minutes during the half hour before and after school. Community walkability also related to MVPA after school only for boys. Some studies tried to compare new urbanist neighbourhoods with conventional suburbs in terms of adults' health outcomes including BMI or walking behaviours ([Rodriguez, Khattak, & Evenson, 2006](#); [Brown, Khattak, & Rodriguez, 2008](#)). The study of [Brown, Khattak, and Rodriguez \(2008\)](#) found no direct relationship between new urbanist neighbourhoods and lower BMI. Only household heads were related to lower BMI. The study of [Rodriguez, Khattak, and Evenson \(2006\)](#) did not find a difference in PA measures across neighbourhoods. In the current study, new urbanist participants had a higher number of both walking and biking days, and this difference shows how new urbanist neighbourhoods support AST.

Especially for the child population, varied moderating factors including demographic, family, school and social environmental factors may affect the relationship between BE and their PA and IAT, and, in addition, parents play a significant role in decisions about PA and IAT. Walkable new urbanism designs are increasing in popularity, but the children's AT patterns in these community designs need research attention.

In the meta-analysis of studies of correlations among BE, PA and walking/ biking, evidence is mixed and not consistent ([Wong, Faulkner, & Buliung, 2011](#); [Pont et al., 2009](#)). As Wong (2011) argues, physically active participants may know more about how their neighbourhood promotes PA than inactive ones. Thus, active and inactive participants located within the same neighbourhood may indeed have very different perceptions about the environment in which they live. Even objectively measured BE variables using geographic information systems (GIS) in different studies have theoretical and methodological inconsistencies in geocoding, buffer methods and quality of infrastructure data and so on ([Wong, Faulkner, & Buliung, 2011](#)).

5.3 School Siting Policies

The research findings stress the importance of school locations and the determination of schools' attendance areas in both conventional and new urbanism neighbourhoods. Minimum acreage requirements and building code issues need to be re-considered ([Zhu & Lee, 2009](#)). Examining environmental predictors of AST provides a guide for stakeholders regarding where to site new schools and how to prioritize improvement projects for the existing environment around schools. Before selecting school sites, stakeholders should consider neighbourhood characteristics, such as distance to school, density, mixture of uses, street connectivity, and sidewalk networks. Not only urban form characteristics, but also traffic treatments such as speed limits, traffic signs, and guarded crosswalks are key components for pedestrian safety. Thus, in the case of limited funds,

treatments for traffic safety or temporary asphalt sidewalk connectivity should be considered first to accommodate pedestrian demand.

6. CONCLUSION

Neighbourhoods exemplifying new urbanist design principles may support children's active school travel more than conventional neighbourhood designs. Maps indicated that integrated trail, park, home and school locations created safe environments for AST (especially biking). Further examination of the association of these factors with *objectively* measured children's AST is required to improve understanding of correlates, mediators and moderators to more confidently support policy development and design interventions to increase children's AST that provide health promotion opportunities to children.

REFERENCES

- Brown, A. L., Khattak, A. J., & Rodriguez, D. A. (2008). "Neighbourhood Types, Travel and Body Mass: A Study of New Urbanist and Suburban Neighbourhoods in the Us". *Urban Studies*, 45(4), 963-988. doi: <http://doi.org/10.1177/0042098007088477>.
- Cain, K. L., Sallis, J. F., Conway, T. L., Van Dyck, D., & Calhoun, L. (2013). "Using Accelerometers in Youth Physical Activity Studies: A Review of Methods". *Journal of Physical Activity & Health*, 10(3), 437-450. doi: <https://doi.org/10.1123/jpah.10.3.437>.
- Centers for Disease Control and Prevention (CDC). (2005). "Barriers to Children Walking to or from School - United States, 2004". *Morbidity and Mortality Weekly Report*.
- Cervero, R., & Kockelman, K. (1997). "Travel Demand and the 3ds: Density, Diversity, and Design". *Transportation Research Part D-Transport and Environment*, 2(3), 199-219. doi: [https://doi.org/10.1016/S1361-9209\(97\)00009-6](https://doi.org/10.1016/S1361-9209(97)00009-6).
- Chillon, P., Evenson, K. R., Vaughn, A., & Ward, D. S. (2011). "A Systematic Review of Interventions for Promoting Active Transportation to School". *The International Journal of Behavioral Nutrition and Physical Activity*, 8, 10. doi: <http://doi.org/10.1186/1479-5868-8-10>.
- Davison, K. K., Werder, J. L., & Lawson, C. T. (2008). "Children's Active Commuting to School: Current Knowledge and Future Directions". *Preventing Chronic Disease*, 5(3), A100.
- Duncan, M. J., & Mummery, W. K. (2007). "Gis or Gps? A Comparison of Two Methods for Assessing Route Taken During Active Transport". *American Journal of Preventive Medicine*, 33(1), 51-53. doi: <http://doi.org/10.1016/j.amepre.2007.02.042>.
- Ewing, R., Schroeder, W., & Greene, W. (2004). "School Location and Student Travel Analysis of Factors Affecting Mode Choice". *Transportation research record*, 1895(1), 55-63. doi: <https://doi.org/10.3141/1895-08>. Retrieved from <https://journals.sagepub.com/doi/abs/10.3141/1895-08>.
- Freedson, P., Pober, D., & Janz, K. F. (2005). "Calibration of Accelerometer Output for Children". *Medicine & Science in Sports & Exercise*, 37(11), S523-S530. doi: <http://doi.org/10.1249/01.mss.0000185658.28284.ba>.
- Gaster, S. (1992). "Historical Changes in Children's Access to U.S. Cities: A Critical Review". *Children's Environments*, 9(2), 34-55.
- Hart, R. (1979). *Children's Experience of Place*. New York: Irvington Publishers, INC. Retrieved from https://www.researchgate.net/publication/232568424_Children's_Experience_of_Place.
- Hillman, M., Adams, J. A., & Whitelegg, J. (1990). *One False Move : A Study of Children's Independent Mobility*. London: Policy Study Institute. Retrieved from <http://john-adams.co.uk/wp-content/uploads/2007/11/one%20false%20move.pdf>.
- Jago, R., Thompson, J. L., Page, A. S., Brockman, R., Cartwright, K., & Fox, K. R. (2009). "Licence to Be Active: Parental Concerns and 10-11-Year-Old Children's Ability to Be Independently Physically Active". *Journal of Public Health*, 31(4), 472-477. doi: <http://doi.org/10.1093/pubmed/fdp053>.

- Joe, L., Carlson, J. L., & Sallis, J. F. (2018). "Active Where? Individual Item Reliability Statistics Parent/Adolescent Survey".
- Kytta, M. (2004). "The Extent of Children's Independent Mobility and the Number of Actualized Affordances as Criteria for Child-Friendly Environments". *Journal of Environmental Psychology*, 24(2), 179-198. doi: [http://doi.org/10.1016/S0272-4944\(03\)00073-2](http://doi.org/10.1016/S0272-4944(03)00073-2).
- Kytta, M. (1997). "Children's Independent Mobility in Urban, Small Town, and Rural Environments". In Camstra, R. (Ed.), *Growing up in a Changing Urban Landscape* (pp. 41-52). Assen: Royal Van Gorcum.
- Larsen, K., Gilliland, J., Hess, P., Tucker, P., Irwin, J., & He, M. (2009). "The Influence of the Physical Environment and Sociodemographic Characteristics on Children's Mode of Travel to and from School". *American Journal of Public Health*, 99(3), 520-526. doi: <https://doi.org/10.2105/AJPH.2008.135319>.
- Matthews, H., Limb, M., & Taylor, M. (2000). "The 'Street as Thirdspace'". In Holloway, S. L. & Valentine, G. (Eds.), *Children's Geographies : Playing, Living, Learning* (pp. 63-79). London: Routledge.
- Mavoa, S., Oliver, M., Witten, K., & Badland, H. M. (2011). "Linking Gps and Travel Diary Data Using Sequence Alignment in a Study of Children's Independent Mobility". *International Journal of Health Geographics*, 10, 64. doi: <http://doi.org/10.1186/1476-072X-10-64>.
- McDonald, N. C. (2007). "Active Transportation to School: Trends among U.S. Schoolchildren, 1969-2001". *American Journal of Preventive Medicine*, 32(6), 509-516. doi: <https://doi.org/10.1016/j.amepre.2007.02.022>.
- Mitra, R., Buliung, R. N., & Faulkner, G. E. (2010). "Spatial Clustering and the Temporal Mobility of Walking School Trips in the Greater Toronto Area, Canada". *Health & Place*, 16(4), 646-655. doi: <http://doi.org/10.1016/j.healthplace.2010.01.009>.
- Moore, R. C. (1986). *Childhood's Domain : Play and Place in Child Development*. London: Croom Helm.
- Moore, R. C., & Young, D. R. (1978). "Childhood Outdoors: Toward a Social Ecology of the Landscape". In Altman, I. & Wohlwill, J. (Eds.), *Children and the Environment*. New York: Plenum
- Natural Learning Initiative (NLI). (2010). *Pathways for Play: Best Practice Guidelines*. Chattanooga: TN: PlayCore. Retrieved from <https://www.playcore.com/programs/pathways-for-play>.
- O'Brien, M., Jones, D., Sloan, D., & Rustin, M. (2000). "Children's Independent Spatial Mobility in the Urban Public Realm". *Childhood-a Global Journal of Child Research*, 7(3), 257-277. doi: <https://doi.org/10.1177/0907568200007003002>.
- Panter, J. R., Jones, A. P., & van Sluijs, E. M. (2008). "Environmental Determinants of Active Travel in Youth: A Review and Framework for Future Research". *The International Journal of Behavioral Nutrition and Physical Activity*, 5, 34. doi: <http://doi.org/10.1186/1479-5868-5-34>.
- Pate, R. R., Freedson, P. S., Sallis, J. F., Taylor, W. C., Sirard, J., Trost, S. G., & Dowda, M. (2002). "Compliance with Physical Activity Guidelines: Prevalence in a Population of Children and Youth". *Annals of Epidemiology*, 12(5), 303-308. doi: [http://doi.org/10.1016/s1047-2797\(01\)00263-0](http://doi.org/10.1016/s1047-2797(01)00263-0).
- Piaget, J., & Inhelder, B. (1963). *The Child's Conception of Space*. London: Routledge & Kegan Paul.
- Pont, K., Ziviani, J., Wadley, D., Bennett, S., & Abbott, R. (2009). "Environmental Correlates of Children's Active Transportation: A Systematic Literature Review". *Health & Place*, 15(3), 827-840. doi: <http://doi.org/10.1016/j.healthplace.2009.02.002>.
- Rodriguez, D. A., Cho, G. H., Elder, J. P., Conway, T. L., Evenson, K. R., Ghosh-Dastidar, B., . . . Lytle, L. (2012). "Identifying Walking Trips from Gps and Accelerometer Data in Adolescent Females". *Journal of Physical Activity & Health*, 9(3), 421-431. doi: <http://doi.org/10.1123/jpah.9.3.421>.
- Rodriguez, D. A., Khattak, A. J., & Evenson, K. R. (2006). "Can New Urbanism Encourage Physical Activity? Comparing a New Urbanist Neighborhood with Conventional Suburbs". *Journal of the American Planning Association*, 72(1), 43-54. doi: <https://doi.org/10.1080/01944360608976723>.
- Sirard, J. R., & Slater, M. E. (2008). "Walking and Bicycling to School: A Review". *American Journal of Lifestyle Medicine*, 2(5), 372-396. doi: <http://doi.org/10.1177/1559827608320127>.

- Staunton, C. E., Hubsmith, D., & Kallins, W. (2003). "Promoting Safe Walking and Biking to School: The Marin County Success Story". *American Journal of Public Health*, 93(9), 1431-1434. doi: <https://doi.org/10.2105/AJPH.93.9.1431>.
- Stevens, R. B., & Brown, B. B. (2011). "Walkable New Urban Leed_Neighborhood-Development (Leed-Nd) Community Design and Children's Physical Activity: Selection, Environmental, or Catalyst Effects?". *International Journal of Behavioral Nutrition and Physical Activity*, 8, 139. doi: <http://doi.org/10.1186/1479-5868-8-139>.
- U.S. Department of Health and Human Services (HHS). (2008). "Physical Activity Guidelines for Americans". U.S. Department of Health & Human Services. Retrieved from <https://www.hhs.gov/fitness/be-active/physical-activity-guidelines-for-americans/index.html>.
- US Department of Transportation (DOT). (1972). "1969 National Personal Transportation Survey: Travel to School". Washington, DC: US Department of Transportation. Retrieved from <http://www.fhwa.dot.gov/ohim/1969/q.pdf>.
- US Environmental Protection Agency (EPA). (2003). "Travel and Environmental Implications of School Siting". Washington, DC: US Environmental Protection Agency. Retrieved from Available at http://www.epa.gov/smartgrowth/pdf/school_travel.pdf.
- van Vliet, W. (1983). "Exploring the Fourth Environment". *Environment and Behavior*, 15(5), 567-588. doi: <https://doi.org/10.1177/0013916583155002>.
- Wong, B. Y., Faulkner, G., & Buliung, R. (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: <https://doi.org/10.1186/1479-5868-8-39>.
- Wong, B. Y., Faulkner, G., Buliung, R., & Irving, H. (2011). "Mode Shifting in School Travel Mode: Examining the Prevalence and Correlates of Active School Transport in Ontario, Canada". *BMC Public Health*, 11, 618. doi: <https://doi.org/10.1186/1471-2458-11-618>.
- Zhu, X., & Lee, C. (2009). "Correlates of Walking to School and Implications for Public Policies: Survey Results from Parents of Elementary School Children in Austin, Texas". *Journal of Public Health Policy*, 30(Suppl 1), S177-S202. doi: <https://doi.org/10.1057/jphp.2008.51>.