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Developing a Measure of Traffic Calming Associated with Elementary School Students' Active Transport

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Abstract

The objective of this study is to develop a measure of traffic calming with nationally available GIS data from NAVTEQ and to validate the traffic calming index with the percentage of children reported by school administrators as walking or biking to school, using data from a nationally representative sample of elementary schools in 2006–2010. Specific models, with and without correlated errors, examined associations of objective GIS measures of the built environment, nationally available from NAVTEQ, with the latent construct of traffic calming. The best fit model for the latent traffic calming construct was determined to be a five factor model including objective measures of intersection density, count of medians/dividers, count of low mobility streets, count of roundabouts, and count of on-street parking availability, with no correlated errors among items. This construct also proved to be a good fit for the full measurement model when the outcome measure of percentage of students walking or biking to school was added to the model. The traffic calming measure was strongly, significantly, and positively correlated with the percentage of students reported as walking or biking to school. Applicability of results to public health and transportation policies and practices are discussed.

Keywords

Traffic Calming; GIS-measures; physical activity; active transport; walking and biking to school

1. Introduction

In the United States and globally, improving levels of physical activity has become a primary goal of public health (U.S. Department of Health and Human Services, 2010; WHO,

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Competing Interest

Competing Interest: None to declare.

2012). Walking and biking are two of the most common forms of physical activity and, when conducted as a means to get from one location to another (as opposed to recreational physical activity), they are referred to as transportation physical activity or active transport. Prior studies have found active transport to be facilitated where supportive built environment infrastructure (including sidewalks, bicycle lanes, and traffic calming elements) exists (Brownson et al., 2009). The fields of transportation and public health have come together in recent years to focus on specific GIS-derived measures of the built environment infrastructure (i.e., land-use and street connectivity) with some studies even combining measures to create indices (Saelens and Handy, 2008). However, many studies to date have been by subjective and survey-based measures of parental perceptions of the built environment (Panter et al., 2010), studies of the built environment in select locations (Tester et al., 2004; de Vires et al., 2010), or meta analyses (Bunn et al., 2003). Even a strong study that validated a GIS-derived measure against a field audit and linked it to physical activity among adults was conducted in a narrow geographic region (Hanja et al., 2013).

While research has established that walking and cycling among adults is increased in more walkable neighborhoods, and those with interconnected streets, higher residential density, and mixed land use increases (Salelens and Handy, 2008), few studies have examined objective measures of the built environment and walking and biking to school among school-aged children. A recent review of 50 walking and 35 pedestrian injury studies found that only traffic calming and presence of playgrounds/recreation areas were consistently associated with more walking and less child pedestrian injury (Rothman et al., 2014). We expect that traffic calming will likely be associated with walking and biking to school among students in our study. We also expect, although previous studies have found mixed results (Braza, Shoemaker, and Seeley 2004; Bungum, et al., 2009; Kerr et al., 2005) that interconnected streets will be significantly and positively associated with walking and biking to school.

The purpose of this paper is to develop a measure of traffic calming with nationally available GIS data from NAVTEQ and to validate the traffic calming index with a measure of active transport to school, using data from a nationally representative sample of elementary schools in 2006-2010. Analyses used structural equation modeling (SEM), which is a logical methodology for constructing and analyzing the association of objective measures of GIS data with a “latent” construct, and then testing its association with a measure of children’s active transport to school.

2. Data and Methods

2.1 Sample

The geographic focus for this study was the area surrounding a nationally representative sample of elementary schools. The sample of schools was developed by sampling experts at the Institute for Social Research at the University of Michigan who used sampling frames based on the National Center for Education Statistics (NCES) Common Core of Data (CCD) to identify a nationally representative sample of public elementary schools. Because elementary schools vary in grade composition (e.g., kindergarten to third grade, second to fifth grade), all schools were required to include a third grade. Public schools from all

coterminous US states (excluding Alaska and Hawaii) were eligible for sampling. Due to the risk of correlated errors, for schools sampled in multiple years, only the most recent year of data was used. The final sample used in the present study is comprised of a pooled, cross-sectional sample (n=1686 unique schools) located within 47 of the 48 contiguous states (no schools from WY were represented in the final sample, due to the low population density of that state).

2.2 GIS protocols and utilization of GIS variables

ArcGIS 9.1 software was used to geocode schools by the residential street address as provided in the CCD files and validated through screening and recruitment for the survey. Schools that could not be geocoded were excluded from the analysis. Figure 1 shows an example of a hypothetical school (not one in the sample, to protect confidentiality), the technique used to create buffer ring donuts for each school, and how each GIS street attribute was clipped within each buffer. A census of all true street segments was used to create each attribute. Each GIS attribute was created uniquely for the buffer area within a quarter-mile, half-mile, three-quarter-mile, and one-mile radius from each school. The school buffers were established as ring donuts, so each buffer ring is a unique land area, rather than using a cumulative approach. Since results were similar across all buffer zones, results for only the quarter-mile buffer are presented. No school buffer zones were adjacent to one another and none overlapped.

Since there is no consensus in the literature on the items comprising a single measure of traffic calming (Rothman et al., 2014), we began by evaluating existing traffic calming constructs used in the field that were linked to safe walking, but not exclusively walking or biking to school. We decided to utilize the Neighborhood Environment for Active Transport (NEAT) GIS protocols designed during the Twin Cities Walking Study as a template for our own built environment analysis (see Schopflocher, VanSpronsen and Nykiforuk, 2014 for a critique of the validity of the micro-level scale components for this inventory not utilized in this study). NEAT employed a variety of data sources including on-the-ground data collection, U.S. Census Tiger files and MetroGIS (Forsyth et al., 2010, 15 - 19), to address their inventory questions, such as “Are there measures on this [street] segment that could slow down traffic?” (Forsyth et al., 2010, 88). Traffic calming was broadly defined as the percentage of street segments with traffic calming. The following seven types of measures were identified by NEAT researchers, with each coded 1 if present and 0 if absent: (1) Speed bump (speed hump, raised crosswalk, or dips that are intended to slow down traffic); (2) Rumble strips or bumps (included dots, reflectors, or raised concrete strips); (3) Curb bulb out/curb extension; (4) Traffic circle/roundabout; (5) Medians; (6) Angled/On-street parking (that runs along most or the entire segment but does not have to be on both sides of segment); and (7) Other.

However, one of the goals of our project was to use nationally available data that any community could apply to their own street networks, therefore we adapted the NEAT protocols. Our own process required retrofitting NAVTEQ (starting with 2010; 3rd quarter) data with NEAT's approach. Unfortunately, attribute definitions between the NEAT's selected six and NAVTEQ's catalog were slightly incompatible due to data collection

methods. After discussion, it was decided to retain any of the traffic calming attributes present in both the NEAT protocols and NAVTEQ and to maintain NEAT's research variable, traffic calming, as a broadly defined concept. In other words, we examined attributes in NAVTEQ's data that ably addressed the question "Are there measures on this [street] segment that could slow down traffic?" NAVTEQ provided the following attributes, which were all coded 1 = yes and 0 = no unless otherwise noted. The final CFA contained five measures described in detail below: (1) low mobility streets, (2) parking availability, (3) dividers, (4) roundabouts, and (5) intersection density.

Low mobility as an attribute was assigned at the segment level to streets that met all the following criteria: (1) when the functional class = 5, which was applied to roads whose volume and traffic movement were below the level of any functional class; (2) the number of lanes per direction of travel lane category = 1; and (3) the speed category was coded 7 or 8 (7 indicated 6-20 MPH; 8 indicated < 6 MPH). Low mobility applied to all street segments with four-wheel drive, parking lot roads and may have contained speed bumps. All links with low mobility were validated for connectivity, ensuring that there could not be a link classified as non-low mobility contained within a low mobility link. Parking availability was defined as parking permitted on left side of the street segment only, parking permitted on the right side of the street segment only, or parking allowed on both sides of the street segment (yes=1; no=0).

Dividers (a.k.a. medians) are a system to prevent left turns (in right-side driving countries), right turns (in left-side driving countries), and U-turns at divided intersections and in the middle of divided roads. We determined a divider/median was present anytime a street segment or intersection contained a physical separator. We also applied the divider rule to instances where the street segment and node were divided, and U-turns were not allowed from the divided street segment to/from any street segment at the reference intersection or to driveways along the street. Lastly, dividers were applied when the street and intersection were divided, and U-turns were not allowed from the divided street to/from any street at the non-reference intersection or driveways along the street. In sum, if any condition above was found, dividers were coded as present. The NAVTEQ reference manual (2010; figures 6-29) provides a graphic representation of these conditions.

A roundabout is a contiguous loop with consistent one-way traffic throughout the circle that controls the traffic flow from converging roads. NAVTEQ roundabouts are digitized into the dataset if they are greater than or equal to 25 meters (82ft.), so they can be large and they must have a minimum of 2 "arms" (intersecting roads). They are defined as "a contiguous loop with consistent one-way traffic throughout the circle that controls the traffic flow from converging roads." While some are smallish circles embedded in neighborhood districts other traffic circles can have as many as 3 arms and can be high volume/high function/high speed. They differ from roundabouts in that there are more routes and direction options within the circle and are regulated through features such as stop signs and traffic signals. The majority of feeder roads into these roundabouts are of the function class-4 variety; "roads which provide for a high volume of traffic movement at moderate speeds between neighborhoods. These roads connect with higher functional class roads to collect and distribute traffic between neighborhoods." Although we cannot guarantee that the

roundabouts in the buffers are purposefully in place to calm traffic in a school zone, satellite imagery analysis indicates that the roundabouts located in this study are often located in neighborhoods adjacent to school grounds and are not of the very large variety.

It was possible to modify the research protocols for the broadly defined concept of traffic calming using attributes in NAVTEQ, while at the same time remaining within the parameters of NEAT's traffic calming inventory question. Within NEAT, "roundabout," "median," "on street parking" and "other" were, to a large extent, replicable with NAVTEQ data. However, we were unable to find comparable attributes or even substitutes for "speed bump," "rumble strips or bumps," or "curb bulb out/curb extension." Low mobility was a relevant inclusion. To account for the missing attributes with available data, we checked the addition of the attribute of intersection density, which may be correlated with sidewalk presence and curb bulb outs.

Intersection density was defined as the total number of street segments per 1,000 square miles of land area, within the buffer zone.

2.3 Contextual factors

Demographic and socioeconomic data were obtained from the NCES CCD (NCES, 2007). Data were matched to the corresponding year of survey data for the 2006-2007, 2007-2008, and 2008-2009 school years. For the 2009-2010 school year, the 2008-09 CCD data were used, since the 2009-2010 CCD was not available at the time of analysis. Variables included locale (suburb, rural, township, or city) and US census region (South, West, Midwest, and Northeast). The percentage of students eligible for free or reduced-priced meals was used as an indicator of socioeconomic status (SES). Previous analyses (Nicholson et al. 2014) have shown that this measure is an appropriate inverse proxy for community-level SES, such that lower SES schools have higher percentages of students eligible for subsidized meals. This measure was grouped into tertiles for analysis.

2.4 Active transport to school data

Active transport to school was derived from estimated percentages of students walking and biking to school, as reported by administrators at nationally representative samples of US public elementary schools. These data were obtained from an elementary school administrator survey (Turner et al., 2010) that was conducted annually as part of the Robert Wood Johnson Foundation-funded Bridging the Gap program. Data were collected with mail-back surveys conducted during the spring (second-half) of school years 2006-2007, 2007-2008, 2008-2009, and 2009-2010. The survey was mailed to the school principal and a \$100 incentive was offered. Response rates were calculated using the American Association for Public Opinion Research (2011) method number 2 (which counts partial responses as complete). Response rates and number of participating schools across the four years, respectively, were 54.6% (578 schools); 70.6% (748 schools); 61.8% (641 schools); 64.5% (680 schools). The Institutional Review Board at the University of Illinois at Chicago approved the survey protocol.

Two active-transport-to-school survey questions were utilized to create the outcome measure of estimated percentage of students walking or biking to school. The first question

asked whether students were allowed to walk or bike to school, according to school rules. Respondents could select “no,” “yes -only certain grades,” or “yes-all grades.” The second question asked respondents to estimate the percentage of students in their school that they would estimate would walk or bike from home to school on an average school day. Schools that did not allow students to walk or bike to school were coded as 0%. Results did not differ when this subsample of schools that did not allow walking or biking to school were omitted from the analyses.

2.5 Statistical analysis

All descriptive analyses and SEM analyses were conducted using Stata SE, Version 12. Descriptive statistics were first examined to determine the normality of the data. All GIS variables except one (intersection density) violated assumptions of normality (i.e., skewness values >2 and kurtosis values >7). In general, for structural equation modeling, the effect of violating the assumption of normality is that chi-square values may be too large (Type I error, rejecting too many models) and standard errors may be too small (Type I error for significance tests of path coefficients). In Stata, non-normal data can be Satterthwaite-adjusted using a scaled chi-squared test statistic and robust standard errors (Satorra & Bentler, 1994; Yuan & Bentler 1997). To correct the non-normal data distributions, we used the asymptotic distribution free (ADF) estimation for all structural equation models (Browne, 1984), and adjusted standard errors to account for clustering of schools within states; models were run with clustering on state FIPS and bootstrapping with 10 replications. Supplemental examination of Moran's I and Geary's C statistics on SEM model residuals did not indicate a problem of spatial autocorrelation.

Next, we examined potential differences in objective GIS measures across several key school contextual variables: locale, region, and SES. ANOVA tests were used to determine significant differences in means for each GIS measure across school contextual factors, followed by Tukey's correction for multiple comparisons categories.

To develop a single measure of traffic calming and then examine its association with active transport to school, we used confirmatory factor analysis (CFA)/latent factor analysis (LFA). This specific type of SEM was used to identify which objective factors were associated with the latent construct of traffic calming. Several models containing different objective GIS measures with and without correlated errors were tested and are described in detail below in the model specification section. Fit statistics available in Stata 12 were examined to determine which model was the best fit for the data. Following recommendations for assessing SEM fit (Hoyle 2012), we selected a variety of indices to evaluate model fit, choosing three absolute fit indices and two comparative fit indices. As a first indicator of absolute fit, we used the model chi-square, with a non-significant test ($p>.05$) indicating good fit. However, because this index is sensitive to sample size, we also used the root mean square error of approximation (RMSEA); values close to zero are ideal, with a maximum of 0.08 indicating adequate fit. Finally, the standardized root mean of the residual (SRMR) was used as third absolute fit index, with values less than 0.05 indicating good fit. Incremental fit indices compare the chi-square of the model with a null model which assumes that all variables are uncorrelated. The Comparative Fit Index (CFI) and the Tucker-Lewis (or Non-

Normed Fit) Index (TLI) are two of the most popular incremental fit indices; for both, values range from 0.0 to 1.0, with values above 0.95 indicating good fit.

Once the best fit for the latent construct of traffic calming was determined, the percentage of students engaged in active transport to school was added to test the measurement model. Fit indices described above and regression coefficients were examined to determine whether the latent traffic calming construct was associated with percentage of students reported as engaging in active transport (i.e., walking or biking) to school.

4. Results

Table 1 presents the means and standard deviations for all objective GIS measures (dividers, low mobility streets, parking, roundabouts, and intersection density), across several key demographic variables of region, locale, and SES. Regional differences indicated that the West, with 292 sampled schools in the state of California, averaged significantly more dividers and low mobility streets than any other region. Additionally, the Midwest and the South had significantly lower intersection density than either the West or Northeast. Locale results suggest that GIS variables were similar for cities and suburbs, but fewer traffic calming features were available in rural and township areas, especially dividers, low mobility streets, and lower intersection density. The lower-SES schools were strikingly different from the higher-SES schools in that they had significantly fewer dividers, but significantly higher amounts of parking and denser street networks. Lower-SES schools were predominantly urban schools, which are more integrated into existing residential neighborhoods, which are more likely to have narrow side streets or even one-way streets. Due to sample size restrictions, we were unable to test for interaction effects, but suspect that interacting relationships among region, locale, and SES may explain these findings.

Table 2 shows the SEM graphics for all models considered in these analyses and Table 3 shows all model fit statistics. Models 1-3 are the CFA models; Model 1 began with a 4-item CFA including the original variables derived from the NEAT protocols (dividers, parking, roundabouts, and low mobility street segments). As expected, the chi-square was non-significant, which suggested the model was a good fit for the data. Additional statistics also confirmed good fit (RMSEA=0.000, CFI=1.000, TLI=1.128, and SRMR=0.008). Examination of the standardized regression coefficients, factor loadings, and covariance matrices revealed that all indicators were significant predictors of the latent traffic calming measures, but also suggested that there was a strong covariance between dividers and roundabouts. Therefore, the next step was to add a correlated error between dividers and roundabouts (Model 2). For Model 2, the chi-square statistic remained non-significant, and all statistics continued to confirm a strong fitting model (see Table 3). However, a non-significant likelihood ratio test confirmed that Model 2 was not an improvement over Model 1. Next, to test additional components of traffic calming not captured in the 4 item model, Model 3 added intersection density. All fit statistics demonstrated that Model 3 was an excellent fit for the data. Likelihood ratio tests confirmed it was not an improvement over Model 2, but was a significant improvement over Model 1.

Model 3 served as the CFA model used to build the measurement model, and to examine the association of traffic calming with the administrator-reported percentage of students engaged in active transport (walking or biking) to school (mean=22.50%, standard deviation=25.97%, median=10.00%, range 0=100%) (Measurement Model: Final Model). Figure 2 presents the graphic model with standardized regression coefficients and standard errors. As shown in Table 3, for the final model, the chi-square statistic remained non-significant, the RSEA was 0.02 (less than 0.05), the CFI of 0.972 and the TLI of 0.954 were both above the 0.95 criteria, and the SRMR remained below 0.05 at 0.041. Regression results indicated that the association between the latent traffic calming construct and the administrator-reported percentage of students engaged in active transport to school was significant, strong, and positive ($\beta=0.48$, s.e.=0.05, $p<.0001$).

As noted above, the total sample of unique schools used in this analysis was 1686. Ideally, it would be possible to test for invariance of model fit for different demographic subsamples, such as higher-SES schools versus lower-SES schools. However, since substantial sample size is needed for ADF distribution models (Browne and Cudeck, 1993); we were unable to conduct such subgroup analyses.

5. Discussion

A major strength of this study is the application of SEM to validate a traffic calming construct. Thus far, few studies in the traffic calming literature have used construct validation (Rothman et al., 2014). Although the application of SEM to traffic studies is growing (Coogan, Adler and Karash, 2012), to our knowledge, this is the first study that uses objective GIS features to develop and validate a latent measure of traffic calming in communities nationwide where a nationally representative sample of elementary schools was located. SEM has many strengths, including the ability to conceptually specify a hypothesized latent variable and to use CFA to confirm (or disconfirm) that latent construct, to test and model correlation among measures, and to improve model fit with the judicious addition of modifications such as correlated errors and/or different path specifications. The current analyses show that there is data available at the national level, not just the local level that yields a valid model for assessing the latent construct of “traffic calming.” Given the validity of this measure, for future research, this same method could be replicated to construct measures of traffic calming around other key neighborhood destinations to examine active travel and physical activity more generally. Further, current studies reiterate the importance of both perceived and actual structure of the built environment are required to support physical activity among adolescents (Hager et al., 2013) and adults (Hanja et al., 2013).

Another major strength of this study is that we were able to use objective data to create a valid model of traffic calming and confirmed that the latent construct was in fact linked to estimated rates of elementary school children's administrator-reported walking or biking to school. The latent construct of traffic calming explained 86% of the variance in administrator-reported estimates of students' walking/bicycling to school. This is very high, and demonstrates the crucial role that built environment factors play in impacting active living. Our results are consistent with previous evidence for the importance of several

commonly studied built environment traffic calming measures (e.g., humps, dividers, traffic circles/roundabouts) and injury prevention (Ewing, 2001; DiMaggio and Li 2013), as well as the importance of street connectedness for promoting safe walking (Bungum et al., 2009). Although not explicitly studied in previous work, our findings on the importance of low mobility streets was consistent with work suggesting that some of the built environment characteristics associated with pedestrian injuries may not be inherently dangerous, but rather serve as markers for increased traffic exposure or for higher speed traffic (Rothman et al., 2014).

Our study has several limitations that should be noted. First, the study utilized a cross-sectional, rather than temporal study design, therefore we cannot ensure causality. Secondly, when trying to explain walking behavior in children, parental perception is important since parents ultimately make the decision of whether or not the child walks to school. Unfortunately, we do not have data on parental perceptions of the neighborhood or built environment, and thus were unable to control for these important covariates. Third, we are somewhat limited by the use of administrator-reported data of students walking/biking to schools, as compared to actual observations or student reports and because a combined question was asked; we are unable to separate out potentially differential effects for walking versus biking to school. Administrator-reported rates of walking/biking to school in this study are higher than rates reported in other studies utilizing parent reports (National Center for Safe Routes to School and Safe Routes to School national Partnership, 2010). Nevertheless, even if the rates used herein are over-estimates we have no reason to believe that such bias would differ systematically across the sample and thus it would not impact correlation between the estimated walking/biking rate and the latent traffic calming construct. Although the sample was relatively large, it was not sufficient to allow for subgroup comparisons, so we were unable to examine differences in fit by region, locale, or SES. A recent study found that student rates of walking to school were higher at schools where greater percentages of students were eligible for free/reduced-priced meals (i.e., lower SES schools) (Su et al., 2013). Additional interventions may be needed to encourage greater rates of active travel to school at higher-SES schools. As supported by our bivariate analysis of traffic calming components, additional walking infrastructures (e.g., stop signs, traffic signals, sidewalks, crosswalks) conducive to active transport to school may be needed in disadvantaged areas to protect children during their active transport. However the costs of modifying built environment features may be a larger challenge in poorer communities and those with older existing infrastructure. The main drawback to using observable NAVTEQ data is that, to our knowledge, the NAVTEQ datasets are no longer available for free to schools or non-profit community institutions. Accessing the data is quite costly, which limits the accessibility and feasibility for many key stakeholders to use the data to evaluate their own built environments and to identify strategies to better meet the needs of their students, with regard to safe active transportation.

6. Conclusions

This study examined and validated a latent construct of traffic calming surrounding schools, using five key components—dividers, roundabouts, parking, low mobility streets, and intersection density. This latent construct of traffic calming was significantly associated with

measures of active travel at the school, such that schools surrounded by more traffic calming measures had higher reported rates of student active travel. This validated traffic calming measure can be a useful tool for local stakeholders including policy makers, urban planners, and school officials to identify future policy interventions and capital improvements to promote active transport and physical activity.

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Highlights

- This study develops and validates a latent measure of traffic calming.
- SEM models indicate that traffic calming is comprised of 5 GIS features.
- Traffic calming is associated with children walking and biking to school.

Figure 1.
GIS protocol for ring donut buffer zones

Note: model presents standardized regression coefficients parallel to path, and percent of variance explained in the lower right corner of variable boxes. As indicated in table 2, PERCTWALK is the percent of students walking or biking to school and ϵ_n indicates the error terms associated with each attribute.

Figure 2.

Final Model of full measurement model with regression coefficients

Table 1

Means and standard deviations of observed GIS variables by important school contextual factors (N=2243 schools)

	Dividers	Low Mobility	Parking	Roundabouts	Intersection Density
Region					
West	0.65 (1.77)	4.11 (9.61)	0.53 (4.91)	0.04 (0.35)	2.05 (1.11)
Midwest	0.20 (0.98) ^a	2.02 (5.68) ^a	0.60 (3.28)	0.01 (0.14)	1.67 (1.05) ^{a,b}
South	0.27 (0.97) ^a	1.86 (8.46) ^a	0.18 (3.23) ^b	0.03 (0.21)	1.50 (1.01) ^{a,b}
Northeast	0.29 (1.17) ^a	2.40 (8.67) ^a	0.91 (5.64)	0.01 (0.10)	1.90(1.68)
Locale					
City	0.52 (1.59)	3.55 (11.38)	1.17 (6.01)	0.02 (0.14)	2.25(1.35)
Suburban	0.45 (1.37)	3.08 (7.60)	0.28 (3.83) ¹	0.04 (0.23)	1.61 (1.01) ¹
Rural	0.09 (0.59) ^{1,2}	1.10 (4.94) ^{1,2}	0.00 (0.00) ¹	0.02(0.27)	1.20 (0.98) ^{1,3}
Township	0.02 (0.19) ^{1,2}	0.59 (1.76) ^{1,2}	0.00 (0.00) ¹	0.02 (0.33)	1.67 (0.98) ^{1,2}
% Students FRL					
High SES school	0.42 (1.36) ⁺	2.75 (6.87)	0.02 (0.45) ⁺	0.04 (0.27)	1.54 (1.00) ^{+,&}
Middle SES school	0.44 (1.49) ⁺	2.26 (7.65)	0.47 (4.77)	0.02 (0.20)	1.75 (1.09) ⁺
Low SES school	0.23 (0.92)	2.66 (8.50)	0.88 (5.05)	0.02 (0.24)	1.91 (1.37)

Notes: FRL indicates free or reduced price lunch

^a significantly different from West

^b significantly different from Northeast

¹ significantly different than City

² significantly different than Suburban

³ significantly different than Township

⁺ significantly different than Highest tertile FRL

[&] significantly different than the Middle tertile FRL

Table 2

Model specification of structural equation model for CFA and measurement models

Model 1: original adaption of the NEAT protocols containing 4-item measure including dividers, low mobility streets, on street parking, and roundabouts
Model 2: adds a correlated error term between dividers and roundabouts, as suggested by the original model results
Model 3: removes the correlated error, which was found to be non-significant, and adds the additional measure of intersection density.
Final Model: adds the percent of students walking/biking to school as an outcome measure

Note: PERCTWALK is the percent of students walking or biking to school and ϵ indicates the error terms associated with each attribute.

Table 3

Fit statistics for all structure equation models (N=2243 schools)

	Confirmatory Factor Analysis Models			Measurement Model
	Model 1	Model 2	Model 3	Final Model
Fit Statistics				
Chi-square	1.07, p=0.59	0.028, p=0.87	7.11, p=0.21	16.38, p=0.06
Root mean squared error (RMSEA)	0.000	0.000	0.014	0.020
Comparative Fit Index (CFI)	1.000	1.000	0.977	0.972
Tucker-Lewis Index (TLI)	1.128	1.266	0.954	0.954
Standardized root mean squared residual (SRMR)	0.008	0.001	0.034	0.041