School Trips

Effects of Urban Form and Distance on Travel Mode

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For over 50 years the U.S. has been shifting away from small, neighborhood schools to larger schools in lower density areas. Rates of children walking and biking to school have declined significantly over this period. This study examines the relationship between urban form, distance, and middle school students walking and biking to and from four schools in Oregon. Five primary results emerge: (1) urban form helps predict travel mode to and from school; (2) middle school students walk further than planners expect; (3) many students use a different mode when they travel to school and when they leave school; (4) urban form measures that predict walking behavior differ from those that predict biking behavior; and (5) urban form is only one factor in students' transportation decisions.

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School siting and student transportation decisions have received increased attention over the last few years due to the rise in childhood obesity and the search for ways to stem this epidemic. This article analyzes the influence of the built environment on middle school students' travel behavior to and from four schools in Oregon. Two schools were located on the urban periphery, while the other two were located in more central neighborhoods with gridded street patterns. Three questions guided this research:

1. How do children get to and from school and what are the reasons behind those choices?
2. What is the relationship between distance from home to school and mode of travel to school?
3. What characteristics of the built environment influence student mode choice?

Background

For over 50 years, communities across the U.S. have been shifting away from small, neighborhood schools to larger schools located in areas where housing densities are low and street networks lack connectivity (U.S. Environmental Protection Agency [EPA], 2003). This occurred in part because of demand for larger sport fields and lack of available, low-cost land in already developed areas (Beaumont & Pianca, 2002; Passmore, 2002; U.S. EPA, 2003).

The trend away from neighborhood schools has been accompanied by a shift in mode of travel to school (Beaumont & Pianca, 2002; Salvesen & Hervey, 2003). Thirty-five years ago, 49% of all students in the elementary and intermediate grades walked or biked to school, whereas only 14% of comparable students do so today (Dellinger & Staunton, 2002). In 1969, 90% of children living within one mile of school walked or biked there compared to about 31% today (Dellinger & Staunton, 2002; Evenson, Huston, McMillen, Bors, & Ward, 2003; Nationwide Household Travel Survey, 2003; U.S. EPA, 2003). This may have reduced opportunities for physical activity among children, increased traffic congestion, and reduced the role that schools have traditionally played in communities (Chung, 2002).

This is worthy of concern because healthy behaviors learned in childhood tend to be carried into adulthood, and active people tend to have longer and healthier lives than less active individuals (Lee, Blair, & Jackson, 1999; U.S. Department of Health and Human Services, 1996, 2002; Wei et al., 1999). The built environment can encourage physical activity (Humpel, Owen, & Leslie, 2002; Lee & Moudon, 2004), although this relationship is complex (Transportation Research Board & Institute of Medicine, 2005). Also complex is the relationship between walking and biking to school and children's overall levels of physical activity (Alexander et al., 2005; Cooper, Page, Foster, & Qahwaji, 2003; Metcalf, Voss, Jeffery, Perkins, & Wilkin, 2004).

Distance to school appears to influence the likelihood of walking there (Black, Collins, & Snell, 2001; Ewing, Schroeer, & Greene, 2004), as would be expected. Those living within one mile of school are the most likely to walk (McMillan, 2003). Other factors, such as population density (Braza, Shoemaker, & Seeley, 2004) and tree cover close to school (McMillan, 2003) have been shown to be positively correlated with rates of walking to school. Factors negatively influencing walking or biking to school include parental perceptions of heavy traffic within their neighborhood (Timperio, Crawford, Telford, & Salmon, 2004) and lack of pedestrian infrastructure such as sidewalks (Boarnet, Anderson, Day, McMillan, & Alfonzo, 2005), among other factors.

A number of GIS approaches have been used to measure walkability and connectivity including block size (Cervero & Kockelman, 1997; Hess, 1997), intersection density (Cervero & Kockelman, 1997; Handy, 1996), route directness (Randall & Baetz, 2001), land use barriers (Fang Zhao, Chow, Li, Ubaka, & Gan, 2003), and commercial density, intensity, and choice (Handy & Clifton, 2000). Straight streets, short block lengths, and good street connectivity indicate walkability (Calthorpe & Poticha, 1993; Ewing & Florida Department of Community Affairs, 1997), as streets shape community interaction and neighborhood life (Southworth & Ben-Joseph, 1997). Thus analyzing street layout with GIS can illuminate the walkability of an area surrounding a school (Schlossberg & Brown, 2004; Schlossberg, Brown, Bossard, & Roemer, 2004).

Method

This study examined the relationship between urban form, distance, and active transportation to school among middle school students. We distributed surveys through each school to households of middle school students, requesting information on mode of transportation to and from school and household address. The addresses enabled us to geocode the location of each respondent's home and calculate individual urban form measures related to students' specific routes to school.

We selected four middle schools of comparable size (see Table 1) to receive surveys, two in Bend, and two in Springfield, Oregon. In each city, one school is newer and located on an urban edge that has few interconnected streets (Sky View and Agnes Stewart) and the other is older and is located in an area with greater street connectivity (Pilot Butte and Springfield).

We based our survey on one previously developed by Smart Ways to School, a program in Lane County, Oregon, funded by the U.S. Environmental Protection Agency (EPA) to reduce the number of cars that carry only one child to school. We refined this survey by reviewing the literature, obtaining input from practitioners, and talking with families at various schools about transportation issues. We aimed to discover, first, what travel mode a child uses to get to and from school. We kept information on journeys to and from school separate, and asked parents to indicate the number of days per week their child uses each of the following travel modes (although we focused on walking and biking): walk, bike, alone in car with parent, carpool, school bus, program van, and other. Secondly, among children who are driven to school, we asked about the factors that influenced the decision to drive, including urban form (e.g., lack of complete sidewalks), and convenience (e.g., desire to drop a child off on the way to work, backpack is too heavy). In all, the survey listed 24 potential responses in a check-all-that-apply format. It does not appear that the ordering of these options strongly influenced responses, as several responses at the middle and end of the list were frequent choices.

The survey also asked basic demographic questions including the student's gender and grade, the number of cars in the household, the family's approximate prior year

Table 1. Characteristics of study schools.

	Year built	Acres	Square footage	Student capacity
Bend				
Sky View	2000	25	113,000	800
Pilot Butte	1967	24	101,803	825
Springfield				
Agnes Stewart	1997	22	94,000	750
Springfield	1950	18	70,389	516

income before taxes, and race/ethnicity. We mailed the survey to parents of each child in the four middle schools. In total, 1,949 surveys were sent and 292 were returned, representing a 15% return rate.

Table 2 presents the demographics of our 2004 sample by city as well as 2000 census data for the two cities. Children in this study are approximately evenly distributed among grades 6, 7 and 8 and by gender. Households of study participants from Springfield were slightly poorer than the city average, while those from Bend were slightly wealthier. As would be expected from an Oregon-based sample, the respondents were overwhelmingly White non-Hispanic (89%), with Hispanics being the largest minority group (7%). Because their shares were so small, Table 2 does not list other groups. Almost all responding households (98%) had at least one car, with most (80%) having two or more.

Measures

The dependent variables in this study are the "primary" modes of travel (three or more days per week) for each student's trips to and from school. We were also interested in predicting whether the child *ever* traveled to or from school by walking or biking, the two active modes.

Table 2. Percentages of the 2004 study population and the 2000 resident population with listed characteristics, by city.

	Total	Springfield		Bend	
Characteristic	**Survey sample (%) (*n*=287)**	**Survey sample (%) (*n*=107)**	**City residents, 2000 Census (%)**	**Survey sample (%) (*n*=180)**	**City residents, 2000 Census (%)**
Distance to school on the street network					
Less than 1 mile	22.0	31.8	Not available	16.1	Not available
1 to <1.5 miles	17.4	16.8	Not available	17.8	Not available
1.5 to <2.5 miles	24.7	22.4	Not available	26.1	Not available
2.5 to <3.5 miles	18.1	17.8	Not available	18.3	Not available
3.5 miles or further	17.8	11.2	Not available	21.7	Not available
Grade of child [a, b]					
6th	28.4	18.4	39.4	34.3	33.5
7th	37.5	44.7	32.7	33.1	29.0
8th	34.2	36.9	27.9	32.6	37.5
Gender of child [a, b]					
Female	52.7	45.8	50.4	56.9	43.0
Male	47.3	54.2	49.6	43.1	57.0
Annual family income					
Less than $30,000	29.7	48.0	36.7	18.6	24.7
$30,000–$59,999	37.5	41.2	39.4	35.3	36.8
$60,000 and over	32.7	10.8	23.9	46.1	38.5
Race/ethnicity					
White (non-Hispanic)	88.8	82.9	86.7	92.5	91.6
Hispanic	7.2	13.3	6.9	3.5	4.6
Other	4.0	3.8	6.4	4.0	3.8
Number of cars in household					
0	1.8	2.8	8.6	1.1	5.8
1	18.2	28.3	38.0	12.3	33.4
2	49.5	45.3	38.2	52.0	42.4
3+	30.6	23.6	15.2	34.6	18.4

Notes:

a. In cases where a family has more than one child in the school, responses are for the youngest child.

b. We used Census data for children ages 12–14 to correspond to responses from 6th–8th graders.

The independent variables in this study are distance from school on the street network and five measures of urban form: intersection density, dead-end density, route directness, major roads, and railroads. Route directness was measured as the ratio of the straight line distance from home to school to the network distance from home to school. We calculated the other four measures of urban form for a ⅛-mile (660 feet) buffer on either side of the shortest network path between each student's geocoded home address and school (an example is shown in Figure 1).

Intersection density, determined by the density of three- and four-way intersections in this ¼-mile wide "walking zone" (number of intersections/zone area) measures opportunities for path choice. We hypothesized that in areas of greater intersection density we would observe more active transportation among children. We also calculated the density of dead-end streets by dividing the number of dead ends by the area of the walking zone. Dead ends result in more circuitous routes, requiring more time and energy, particularly for pedestrians. We hypothesized that in areas with fewer dead ends more students would use active transportation modes. Although using the shortest path to school already controls for dead ends (by definition, one cannot encounter a dead end along the shortest path), we included them in our model because they may play a role in whether the space between home and school is perceived as hospitable to walkers.

The two other urban form measures are dichotomous variables for whether or not a major arterial road (using the TIGER[1] classifications) or railroad intersects the walking zone. Major roads and railroads often act as impediments to pedestrian travel and are often perceived as dangerous by parents, who may restrict their child's modes of transportation if they are present. Therefore, we expected major roads or railroads within the walking zone to reduce the use of active transportation modes.

While studies of general walkability typically include measures of density and land use mix, we have not included any in this study. Such factors help understand whether residents have a variety of daily destinations (e.g., the market, coffee, video store, work, transit stop, etc.) close to home, and therefore accessible by foot. However, since the school is the only destination of interest in our study, we are interested only in the distance and nature of the path network between home and school. We do not expect mixed land use or higher densities to cause a higher proportion of trips to school to be made on foot or to change households' school trip destinations. Indeed, density and land use mix proved to be insignificant in a prior study of the built environment and mode of travel to school (Ewing, Schroeer, & Greene, 2004).

Analytic Approach

We used Chi square analysis to examine the bivariate relationship between distance and transportation mode, establishing five categories of distance to school after preliminary analysis showed mode change to occur at thresholds rather than linearly. We established cut points

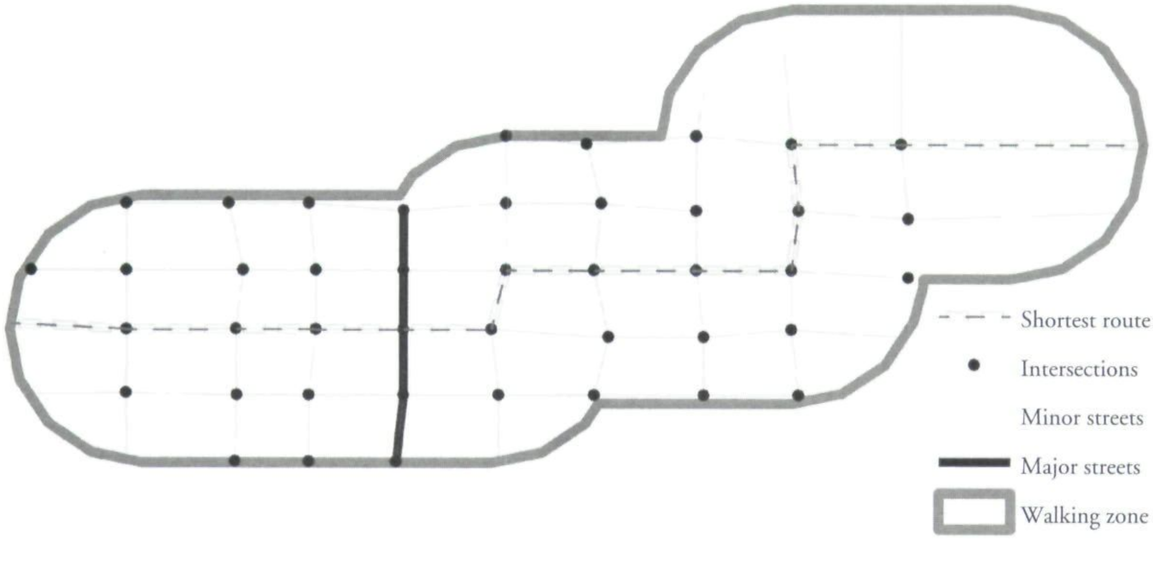

Figure 1. Example of a "walking zone."

using the following three criteria: (1) break at 1.5 miles, above which distance many school districts (including those in our study) provide bus service; (2) create categories with residential populations of comparable size; and (3) break at whole or half-mile distances. We do not show the bivariate relationships between the urban form measures and mode of transportation to and from school, due to space considerations.

We used multivariate logistic regression to isolate the individual relationships of the urban form measures and distance with the dependent variables while controlling for other independent variables. Upon testing, we found that neither income, grade level, ethnicity (Latino or non-Latino), nor number of cars owned by the household predicted mode of transportation, nor did they influence odds ratios for the dependent variables. For the sake of parsimony, they have not been included in the models. Girls were substantially less likely to bike than were boys; however, including gender in the biking models did not influence the key relationships.

We categorized intersection density, route directness, and dead-end density values as low (bottom tercile), medium (middle tercile), and high (top tercile). In addition to the distance categories described above, we also modeled the relationship of mode choice and distance using cubic terms to allow for a more complex functional form. The cubic and categorical approaches yielded similar results, but since the latter was easier to interpret, it is presented here.

The following section presents the adjusted odds ratios from the logistic regression models. We used the models to calculate predicted probabilities to facilitate interpretation, assuming for this purpose that all independent variables except the variable of interest take on their mean values in the sample. If intersection density is the variable of interest, we first assign all respondents a low value for intersection density and calculate the probability of walking to school. Repeating this calculation with middle and high values for intersection density, we isolate the predicted influence of intersection density on the probability of walking to school. We used Stata's cluster option to adjust the standard errors in all statistical testing, since respondents were clustered by school (Stata Corporation, 2003).

Results

About 84% of the children surveyed primarily traveled to school by car or bus, while about 75% returned home by these modes. However, walking or biking was the primary mode for 15% of students on the way to school and about 25% on their way home (see Table 3). Twice as many students walk home from school as walk to school (20% versus 10%). Many parents drive their children to school in the morning on their way to work, but are not available to drive them home at the end of the school day. An additional 10% occasionally walk to or from school. Biking is less popular among our sample of middle school students. About 5% of students bike to and from school as their primary mode of transportation, and 16% report occasionally biking.

As expected, the distance one lives from school was strongly associated in bivariate analysis with mode of transportation (see Table 3). Those who live within one mile of school are by far the most likely to walk, followed by those living 1 to 1.5 miles. For example, 52% of those living less than a mile away walk home from school, compared to 36% living 1 to 1.5 miles away. Beyond 1.5 miles, fewer than 4% walk to or from school. Biking showed a similar pattern. Not surprisingly, travel by bus displayed the opposite relationship, with those living beyond 1.5 miles most likely to ride the bus. Contrary to expectations, however, we observed no relationship between distance to school and travel by car.

Table 4 presents the multivariate models, showing the independent influence of distance and each urban form measure on walking and biking. Adjusting for the measures of urban form, distance to school was still highly associated with walking to and from school. Consistent with the bivariate relationship already discussed, we observed that students who live less than 1 mile from school were the most likely to walk, followed by those living 1 to 1.5 miles away.

Holding distance and other urban form measures constant, intersection density was also a strong predictor of whether or not children walked to and from school. The adjusted odds ratios for those whose walking areas had low intersection density ranged from 0.16 to 0.19 compared to those in high areas (depending on the measure of walking). Using the logistic regression coefficients to calculate predicted probabilities of walking to school, we found that students whose walking areas had high intersection densities had a 10% probability of walking, compared with only 3% and 2% if they had medium or low intersection densities, respectively.

In the multivariate models, fewer dead ends were also predictive of walking. The adjusted odds ratios for walking to and from school were 0.28 and 0.19 respectively for those whose walking areas had high dead-end densities compared those with low dead-end densities. Those with low dead-end densities had an 8% probability of walking to school, holding other factors constant, compared to 3%

Table 3. Chi-square test of percentages of survey respondents using each mode to and from school, by network home to school distance.

		Walk			Bike			Car		Bus	
	Sample size	Ever walk to or from school %	Primary mode to school %	Primary mode from school %	Ever bike to or from school %	Primary mode to school %	Primary mode from school %	Primary mode to school %	Primary mode from school %	Primary mode to school %	Primary mode from school %
All	287	30.0	9.8	19.5	16.0	5.2	5.6	45.5	32.4	38.8	42.2
Distance to school											
<1 mile	63	76.2***	31.7***	52.4***	28.6**	14.3**	15.9**	42.9	22.2	11.1***	9.5***
1 to <1.5 miles	50	46.0	10.0	36.0	22.0	6.0	6.0	60.0	32.0	24.0	26.0
1.5 to <2.5 miles	71	11.3	1.4	2.8	14.1	2.9	2.8	40.0	31.0	55.7	63.4
2.5 to <3.5 miles	52	7.7	3.8	3.8	7.7	0.0	0.0	36.5	32.7	55.8	61.5
3.5+ miles	51	5.9	0.0	2.0	5.9	2.0	2.0	51.0	47.1	47.1	49.0

*$p < .05$ **$p < .01$ ***$p < .001$

and 2% for those with medium and high dead-end densities, respectively.

We found no evidence, however, that a major road or railroad on the route to school influenced walking to or from school. Similarly, route directness was not a consistent predictor of walking. Taken together, distance and urban form factors predicted between 32% and 41% of the variation in whether the student ever walked to school or whether walking was the primary mode either to or from school.

Distance from school was a predictor of biking in multivariate analyses, but the urban form measures did not appear to influence children's biking to or from school. As we found in bivariate analysis, the greater the distance to school, the less likely one was to bike. However, only those living 2.5 or more miles away from school were statistically less likely to bike than those living 1 mile from school (adjusted odds ratios ranged from 0.04 to 0.20 depending on the biking measure). Since urban form measures were not predictive of biking, the overall predictive power was much weaker than the walking models. Pseudo-R^2 values ranged from 9% to 16%.

Table 5 shows the primary reasons parents give for why approximately half the sample (49%) are usually driven to or from school (Table 5). The most common reasons relate to convenience: ease of dropping child off on the way to work (41%), the heaviness of the child's backpack (33%), and bad weather (30%). Neighborhood walkability concerns were expressed by some, with almost one quarter (23%) complaining of dangerous traffic conditions, 15% of high-speed vehicles, and 13% of lack of complete sidewalks.

We also examined the association between distance from school and reasons for driving. We found that parents whose children lived both nearer and further than 1.5 miles from school expressed equivalent concern with neighborhood walkability. Those who lived near middle schools were more likely to report driving their children because of factors unrelated to the urban form and planning (fear of strangers, need to transport musical instruments or projects, etc.) while among those who lived further away, distance was the dominant explanation, overshadowing these other concerns, although they may still exist.

In sum, we found that measures of urban form and distance to school were highly associated with whether middle school children walk to and from school, while only distance to school was predictive of biking. Children whose routes to school had higher intersection densities and lower dead-end densities were more likely to walk, holding other factors constant. Distance to school did not predict whether children would be driven to or from school, in either bivariate or multivariate models (the latter not shown). A child who lived within 1 mile of school was as likely to be driven to school as a child living 3 miles away.

Table 4. Adjusted odds ratios from logistic regression models predicting children's active transport to and from school.

Distance and urban form measures	Walk: Ever walk to or from school	Walk: Primary mode to school	Walk: Primary mode from school	Bike: Ever bike to or from school	Bike: Primary mode to school	Bike: Primary mode from school
Home to school distance						
<1 mile	—	—	—	—	—	—
1 to <1.5 miles	0.21**	0.27*	0.68	0.78	0.37	0.32
1.5 to <2.5 miles	0.04***	0.05***	0.04***	0.47	0.13	0.10
2.5+ miles	0.02***	0.07**	0.04***	0.20**	0.05*	0.04*
Intersection density						
Low (<3)	0.17**	0.16*	0.19**	1.43	1.88	2.04
Medium (3 to <6)	0.39*	0.29*	0.27**	1.34	1.35	1.76
High (6+)	—	—	—	—	—	—
Dead end density						
Low (<18)	—	—	—	—	—	—
Medium (18 to <33)	0.37*	0.32	0.21**	1.02	1.39	1.74
High (33+)	0.48	0.28*	0.19**	0.81	0.96	0.84
Route directness						
Low (1.43+)	2.40	1.11	2.11	1.42	0.65	0.81
Medium (1.26 to <1.43)	1.06	0.73	0.87	1.09	0.63	0.60
High (<1.26)	—	—	—	—	—	—
Major road on route						
Yes	2.17	0.49	0.56	0.65	1.53	1.21
No	—	—	—	—	—	—
Railroad tracks on route						
Yes	0.21**	1.35	0.38	0.56	0.41	0.69
No	—	—	—	—	—	—
Pseudo-R^2	0.41	0.32	0.41	0.09	0.15	0.16

*$p < .05$ **$p < .01$ ***$p < .001$

Implications for Planners and Policymakers

We take five lessons from this work, all of which have planning and policy implications.

1. *Urban form matters with regard to walking to school.* Intersection density and dead-end density are significant predictors of walking rates to and from school, as is distance to school, which is a product of urban form. Therefore, planners and school administrators should pay careful attention to the mobility infrastructure around schools if facilitating active transportation is an important goal. This is especially relevant when new schools are built on the urban fringe in anticipation of future population growth. Streets around such new schools should provide choices of routes with an adequate supply of local roads rather than funneling all traffic to one or two arterials.
2. *Students will walk further tha.. the one half mile to middle school commonly assumed.* We found that a substantial percentage of students living up to 1.5 miles from school walked at least occasionally. This has important implications for planners, who usually assume children walk only for shorter distances. Planners and policymakers interested in active transportation to school should consider the implications

Table 5. Chi-square test of percentages of parents giving various reasons for driving child to school, by distance to school.

Reason for driving child to school	% of those who usually drive child to school (n=142)	% by distance to school <1.5 miles (n=57)	% by distance to school 1.5 miles and more (n=85)
Drop off on way to work	41.5	45.6	38.8
Backpack too heavy	33.1	40.4	28.2
Bad weather	30.3	43.9	21.2**
Dangerous traffic conditions	23.2	24.6	22.4
Too far to walk/bike	22.5	10.5	30.6**
Before/after school activities	21.1	15.8	24.7
Afraid of strangers	18.3	26.3	12.9*
Projects or musical instruments to transport	17.6	26.3	11.8*
High-speed vehicles	15.5	15.8	15.3
Lack of complete sidewalks	13.4	14.0	12.9
Pick up on way from work	12.0	8.8	14.1

$^{*}p < .05$ $^{**}p < .01$ $^{***}p < .001$

of their land use and transportation decisions for a larger area around new and existing school locations.

3. *Rates of walking to and from school are different.* Fewer students walk to school than from school. Most students start school at the same time, and go directly from home to school in the morning. At the end of the school day, however, students have a variety of on- and off-site after-school activities that may divert or delay the trip home. Given this, the morning trip lends itself more easily to organized interventions such as the Walkbus or Walkpool, in which groups of children, generally accompanied by an adult, walk to school together.
4. *Urban form measures that predict walking may not predict biking.* Our urban form measures seem to capture an environment's suitability for walking better than its suitability for biking. These two active modes are distinct, and planners and researchers should separate them, recognizing that each has its own issues and requires its own measures.
5. *Parents have compelling reasons for driving their children to school that are unrelated to urban form and distance.* If it is convenient for a parent to drop their child at school on the way to work, then perhaps no infrastructure or urban design improvement would induce them to do otherwise. Parents also cite other issues such as personal safety (e.g., fear of strangers), comfort (e.g., weather), and school requirements (e.g., carrying books or instruments) as key reasons that children do not walk or bike to school. Planning interventions can only overcome some of the barriers to increased active transport.

Limitations of the Study

The most important limitations of this study are that our sample is not widely representative, being based on a cross section of students in two small cities in Oregon, and that given the study's low response rate, it is possible that the respondents differ systematically from nonrespondents in how children get to school. It is also true that cross-sectional studies establish only association, not causality. We cannot say whether urban form attributes cause children to walk more or whether families who prefer that their child walk choose neighborhoods with more walkable urban form.

Less importantly, we used the street network as a proxy for paths that students who walk or bike would use to get to school. This approach assumes that children travel only on streets and that all streets have sidewalks, although paths through open lots, parking lots, or parks would be attractive alternatives for children's journeys. Similarly, we have classified the street network into minor and major roads utilizing the standard classifications that are embedded into TIGER street data. A more nuanced approach would rate the walkability of each street segment, classifying them as "friendly" or "hostile."[2] Finally, the size of the sample limited our ability to examine differences in walking patterns among those living less than 1 mile from their schools.

Conclusion

School siting and access is increasingly of interest to planners, policymakers, school administrators, and public health officials as a variety of research links lack of physical activity to long-term health problems (Centers for Disease Control and Prevention, 1997; U.S. Department of Health and Human Services, 2001). While walking or biking to school represents only one piece of the overall health puzzle, it is significant because walking or biking to school provides regular physical activity, and perhaps more importantly, because exposing children to walking and biking at an early age can help build healthy habits, increasing the likelihood that they will use these modes of transport later in life. This research adds to our understanding of how the built environment influences student travel choices.

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Notes

1. TIGER (Topographically Integrated Geographic Encoding and Referencing) is a national system of digital map files that allows addresses to be converted to points on a map.

2. We are experimenting with this more nuanced approach to classifying street segments. We have converted the Pedestrian Environment Data Scan (PEDS), developed by Dr. Kelly Clifton at the University of Maryland, into a GIS-based, mobile data entry system (on a Personal Digital Assistant) and used it to classify some streets around each of the case study schools. These data were not extensive enough to use for this study, but we are continuing to evaluate the potential of this pedestrian audit instrument to help construct a more refined model of the local pedestrian environment.

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