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Children's mode choice for the school trip: the role of distance and school location in walking to school

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Abstract Rising levels of childhood obesity in the United States and a 75% decline in the proportion of children walking to school in the past 30 years have focused attention on school travel. This paper uses data from the US Department of Transportation's 2001 National Household Travel Survey to analyze the factors affecting mode choice for elementary and middle school children. The analysis shows that walk travel time is the most policy-relevant factor affecting the decision to walk to school with an estimated direct elasticity of −0.75. If policymakers want to increase walking rates, these findings suggest that current policies, such as Safe Routes to School, which do not affect the spatial distribution of schools and residences will not be enough to change travel behavior. The final part of the paper uses the mode choice model to test how a land use strategy—community schools—might affect walking to school. The results show that community schools have the potential to increase walking rates but would require large changes from current land use, school, and transportation planning practices.

Keywords Children · School travel · Mode choice · Community schools · Walking

Introduction

Concern about rising levels of obesity in children and adults has led the U.S. Surgeon General to recommend "regular, moderate physical activity" as an important component of a healthy lifestyle (Jackson 2003). Research has shown that many children are not attaining the physical activity recommended by the Surgeon General. Rates of overweight (defined

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as at or above the 95th percentile of the sex-specific body mass index) increased from 6% in 1971–1974 for ages 12–19 to 17% in 2003–2004; similar increases were seen in other age categories (Ogden et al. 2006).

The rise in childhood obesity has occurred at the same time children have radically changed how they get to school. In 1969, 42% of American students walked or biked to school (Beschen 1972); by 2001 that number had dropped to less than 15% (McDonald 2007a). Overall children now make nearly 80% of their trips by auto (Surface Transportation Policy Project et al. 2003) and only 20% of U.S. students walked or biked enough to gain health benefits (Kann et al. 1998).

Many researchers believe that if more children walked or biked, it might be possible to lower children's health risks (Tudor-Locke et al. 2001). Policymakers have begun to support the goal of getting children to walk to school. The Centers for Disease Control has launched the KidsWalk program to encourage children to walk to school. Several states facilitate walking to school through their Safe Routes to School (SR2S) programs, which fund improvements near school sites. The current federal transportation bill, SAFETEA-LU, contains over $600 million for a national Safe Routes to School program. While these programs are important, they presume that safety rather than distance is the primary barrier to walking to school.

This research tests the hypothesis that the current spatial distribution of students and schools leads to long trip distances and is a primary reason for the current low rates of walking to school. Using a multinomial modeling framework, I identify how trip length, controlling for individual and household characteristics, influences the decision to walk to school. The model results are then used to predict how urban planning and design strategies, which address the spatial distribution of schools and students—such as community schools—could affect how children travel to school.

Previous research

Across the developed world, children have become increasingly reliant on automobiles for their mobility. In the US, over 75% of children's trips are in private vehicles (Surface Transportation Policy Project et al. 2003). Children in Melbourne, Australia use autos for 70% of their travel (Ampt 1996). Part of the reason for the use of cars is that parents are not allowing children to travel alone. Hillman et al. (1990) showed that English schoolchildren had less travel freedom in 1990 than in 1971. For example, 50% of schoolchildren aged 6 to 11 were allowed to ride buses alone in 1971; while only 14% were allowed to do so in 1990. What is not yet clear is how much the reliance on automobiles has contributed to children's obesity.

A study of Russian children showed that walking to school provided a substantial portion of children's physical activity in Russia (Tudor-Locke et al. 2002). Work in the Philippines has also shown that children who walk to school also had higher levels of total physical activity (Tudor-Locke et al. 2003). Cooper et al. (2003) found that primary school boys in the United States who walked to school had higher levels of physical activity afterschool and in the evenings than their peers. One contradictory study concluded that walking to school represented only 2% of weekly physical activity for 5-year-old British boys and did not lead to an increase in overall physical activity (Metcalf et al. 2004). However, the very restricted focus of this work (5-year-old boys) leads to questions about the generalizability of the findings. While the current focus is on obesity, a separate body of research suggests walking to school also provides an important step in children's maturation by allowing them to acquire the skills necessary to negotiate the world independently (Banerjee and Lynch 1977; Hillman et al. 1990).

Key factors

Researchers have identified several factors which influence travel behavior in children, particularly the decision to walk. Studies in the United States (McMillan 2007; McDonald 2007b; Schlossberg et al. 2006), the United Kingdom (Black et al. 2001), and Australia (Timperio et al. 2006) have shown distance to be a critical factor in children's travel. Girls are less likely to walk than boys with the differences being most prominent at younger ages (Evenson et al. 2003; O'Brien et al. 2000) and in suburban areas (Vliet 1983). Household factors such as car ownership and parents driving to work also affect mode choice (Bradshaw and Atkins 1996; DiGuiseppi et al. 1998). The built environment appears to exert a small, but significant, effect on walking to school. In a study of Oregon middle schools, Schlossberg et al. (2006) found that urban form—as measured by higher intersection densities and lower proportions of dead-ends—was associated with walking to school. McMillan's (2007) study of California elementary students found a modest relationship between urban form and walking.

Another factor repeatedly cited is safety. Parents express concern about traffic dangers and the risk of abduction or harassment (Martin and Carlson 2005). Geographers concerned with children's sense of place have noted that safety concerns have led parents to limit the time children spend playing in public spaces, and the safety-imposed restrictions are more severe for girls than boys (Valentine 1997).

Research on SR2S programs has shown that public policies can affect travel behavior. In a study of California elementary schools, Boarnet et al. (2005) showed that the presence of a SR2S infrastructure improvement caused more children to walk and bike when compared to a control group. A separate evaluation of the SR2S programs in Marin County, California showed a 64% increase in walking to school, which the authors attributed to the program (Staunton et al. 2003).

Methodology

This research uses a multinomial logit model to understand mode choice for the trip to school (see Train 2003, for model derivation). The model structure assumes that children and their parents, as a family unit n, choose the child's travel mode, j, to maximize utility, U_{nj}. The assumption that children's travel modes are chosen to maximize household utility is critical, since it is clear that the parents' wishes may completely determine mode choice. Assuming $U_{nj} = V_{nj} + \varepsilon_{nj}$ and ε_{nj} is distributed iid extreme value results in a closed form representation for the probability of choosing each mode, j, for each person, n.

$$\Pr(Y = j)_n = \frac{\exp(V_{nj})}{\sum_{l \in J} \exp(V_{nl})}, \tag{1}$$

where J is the set of available modes.

Model specification

In this model, decision-makers face a choice between driving, walking and taking a school bus or transit to school. The representative utility of each mode for each person, V_{nj}, is a function of trip, child, household, and neighborhood characteristics.

$$V_{nj} = \alpha_j + \beta_j T_{nj} + \delta_j C_n + \gamma_j HH_n, \tag{2}$$

V_{nj} represents the observed utility to person n of mode j; α_j is an alternative specific constant; T_{nj} is the travel time required for person n to complete the journey by mode j; C_n represents the characteristics of the individual such as age and gender; HH_n represents household factors such as income.

Auto is the reference mode, with only auto travel time entering its utility function. In addition, it was assumed that students would value travel time differently for each mode. Therefore, the coefficients on the travel time variables are not constrained to be equal. Factors were retained in the model if they were significant at the 0.05 level or if there was a theoretical or research reason for keeping the variable. Marginal effects are calculated for each individual and then averaged across the sample. Aggregate direct and cross elasticities are also provided for continuous variables.

Choice sets

For the multinomial model, the universal choice set was auto, bus/transit, and walk. Although transit and school bus may seem like very different modes, I have combined them to ensure that this mode is available to all students. In many cities, there is no school bus service. Instead students use public transit to get to school. In many suburban and rural areas, there is no public transit available. Because I have no information on whether a school bus or transit is available for the school trip, I make the assumption that at least one of these modes will be available. Clearly, there are important differences between school buses and public transit—primarily the fact that students share space on public transit buses with adults. This may affect parents' and students' perceptions of safety and comfort for each of these modes. Future research will be needed to study the possibility of analyzing these modes separately. Because very few students biked to school ($\sim 1\%$), I have excluded this mode from the analysis.

Many students live quite far from school, making walking an unrealistic choice. Because of this, I tested a model which eliminated walking from an individual's choice set if estimated walk travel time was greater than 1 h. This restricted the choice set of nearly half of the students in the sample. Analysis of the model with a restricted choice set versus an unrestricted choice set showed no appreciable differences in the coefficients on travel time. Therefore I present results of models estimated with unrestricted choice sets.

Data

Data come from the 2001 National Household Travel Survey (NHTS), the most recent national travel survey collected by the US Department of Transportation. The NHTS provides trip diaries for 66,000 households. Collected between March 2001 and May 2002, the dataset includes information on trip purpose, mode, time, length, as well as who in the

Table 1 Description of variables

Continuous Variables	Mean	Std. Dev	Categorical variables	Percent
Trip distance (km)	6.4	7.4	Female	49.0
Walk travel time (min)	89.2	102.0	Black	5.9
Auto travel time (min)	13.3	14.8	Asian	3.7
Age	9.3	2.5	Latino	4.1
# Of siblings	1.5	1.1	Multi-racial	4.6
Vehicles per driver	1.1	0.5		
Income (US$ 000)	59.9	30.5		
Residential density (1,000 people/km^2)	1.7	5.3		

household was on the trip. The dataset also includes descriptive information for each person, e.g., age, sex, and household, e.g., household size, income, auto ownership, density at residence. Each participating household was assigned a 'survey day' on which they recorded all trips. For the 2001 survey, the survey methodology included prompts to ask respondents about non-motorized trips which tend to be underreported (U.S. Department of Transportation 2004). This new methodology led to a substantial increase in the reporting of walking trips (Pucher and Renne 2003).

This analysis focuses on elementary and middle school, defined as ages 5 through 13, because travel behavior changes dramatically when children reach high school and have much greater auto access (Rhoulac 2005). The unit of analysis is the trip tour from home to school rather than unlinked trips. This accounts for the fact that many children travel with siblings in the morning, often making stops at their schools as well. Tours were included in the analysis if they occurred between September and May, began before 10:30 in the morning, and had no intermediate stops longer than 30 min (approximately 3% of the sample had stops of more than 30 min). In addition, students that biked to school, approximately 1% of students, were eliminated from the analysis. The final requirement was that average travel speeds (computed as self-reported distance divided by self-reported travel time) must be reasonable.[1] This requirement increased the likelihood that self-reported distances were accurate. Given these restrictions, the sample includes 6,508 children from 4,394 households with 47% being driven, 41% taking the bus or transit and 12% walking. Demographic characteristics show that the sample has fewer minority members (6% African-American, 4% Hispanic, and 4% Asian-American), and is higher income than the population of the United States (Table 1).

Variables

The primary trip characteristic is travel time. The usual method of estimating travel times for mode choice models requires an origin-destination travel time matrix. This is impossible with national data. Because of this, I used speed factors to translate the reported trip

[1] The definition of "reasonable" was based on the data. Any walking trips with an average speed of 16 kph (10 mph, the 93rd percentile) or driving trips of 80 kph (50 mph, the 95th percentile) were removed from the sample.

distance into time. The speed factors were calculated from the dataset based on the median travel speeds by mode and whether the household was located in an urbanized area. For auto trips, there were substantial speed differentials depending on whether the household was located in a (census-defined) urbanized area. For example, the median automobile speed in urbanized areas was 25 kph (15 mph) compared with 39 kph (24 mph) for non-urbanized areas. The median walk speed was 4.3 kph (2.7 mph). The average trip distance among all elementary and middle school students was 6.4 km (4.0 miles) (Table 1).

Bus travel times were not included in the model, because their inclusion led to highly unstable models and non-sensical results, i.e., coefficients on the travel time for multiple modes were non-negative. These findings are consistent with Ewing and Greene (2003) who in their analysis of student travel in Florida found it difficult to estimate bus travel times and estimated the model without bus travel times. They asserted their belief that the decision to ride the bus is made without regard to bus travel time. Further research is needed to refine the definition of trip characteristics for bus travel.

Results

Simple averages show that 48% of students living less than 1.6 km (1 mile) from their school walked compared with a walk rate of 3% for students living more than 1.6 km from their school. However, of the 6,508 children in the study only 20% lived within 1.6 km of their school. The mode choice model provides a more detailed understanding of these descriptive statistics. Because the current debate on children's travel is focused on walking to school, I concentrate my analysis on walking but also present statistics for the effects on the auto mode.

Travel time

The model shows that travel time—in essence distance to school—has the strongest effect on the decision to walk to school (Tables 2 and 3). A 1 min increase in walk travel time leads to a 0.2% decline in an individual's probability of walking; a 10% increase in walk travel time leads to a 7.5% decrease in walk mode share. The direct walk travel time elasticity is quite close to the value estimated by Ewing and Greene (2003) in a study of school travel in Gainesville, Florida. Children are much less sensitive to auto travel times. A 1 min increase in auto travel time leads to a 0.01% increase in the probability of walking; a 10% increase in auto travel time leads to a 0.1% increase in the likelihood of walking.

Child characteristics

Although distance and travel time are the most critical variables, several individual and household level characteristics are also important. A 1 year increase in age leads to a 0.4% increase in the probability of walking and a corresponding 1.4% decline in the likelihood of being driven. Having siblings also makes children less likely to be driven to school and more likely to walk. This effect is likely to result from parents' increased comfort allowing children to walk when they are accompanied by siblings and the increased time costs for parents of dropping off multiple children at school.

Table 2 Multinomial model results

	Auto		Bus/Transit		Walk	
	Coeff.	*P*	Coeff.	*P*	Coeff.	*P*
Intercept			−1.09	<0.01	−0.04	0.90
Trip characteristics						
Auto travel time	−0.01	<0.01				
Walk travel time					−0.08	<0.01
Child characteristics						
Age			0.11	<0.01	0.21	<0.01
Female			−0.14	0.01	−0.12	0.22
Number of siblings			0.12	<0.01	0.22	<0.01
Household characteristics						
Black			0.08	0.29	−0.22	0.08
Asian			−0.01	<0.01	−0.01	<0.01
Latino			−0.09	0.59	0.44	0.07
Multi-racial			−0.83	<0.01	−0.78	0.02
Vehicles per driver			−0.44	0.03	−0.30	0.29
Income (000)			−0.27	0.11	−0.40	0.10
Populational density (000)					0.01	<0.01
Summary statistics						
N	6,508					
Log Likelihood	−5,232					
Model χ^2	494.01					
Prob	<0.01					
Pseudo-R^2	0.27					

Coefficients for dummy variables for Census Region and Season have been ommited for space reasons

One consistent finding in the limited literature on children's travel is that girls have a more circumscribed travel world than boys which leads them to make fewer independent and walking trips than boys (Hillman et al. 1990; O'Brien et al. 2000; McMillan 2006; Vliet 1983). The behavior of children in this sample is contrary to the previous research. The gender variable is not significant in the walk equation. There is some evidence that girls are less likely to ride buses, but the effect is not strong.

Household Characteristics

At the household level, income has moderate effects on travel behavior. For example, increasing income by 10% leads to a 2.6% decline in walking and a 2% increase in being driven. The effects of race and ethnicity on walking are quite modest, especially given the large differences in unadjusted walk rates by race. For example, 10% of whites walk to school while 22% of African-American children walk. However, the apparent racial variation is mostly explained by factors such as household income, density, and neighborhood composition.

Table 3 Marginal effects and elasticities

	Auto		Walk	
	Marginal effect	Aggregate elasticity	Marginal effect	Aggregate elasticity
Trip characteristics				
Auto travel time	−0.001	−0.078	0.000	0.010
Walk travel time	0.001	0.104	−0.002	−0.748
Child characteristics				
Age	−0.014	−0.577	0.004	0.820
Female	0.015		−0.001	
Number of siblings	−0.015	−0.100	0.004	0.154
Household characteristics				
Black	0.001		0.011	
Asian	0.087		−0.010	
Latino	0.046		−0.003	
Multi-racial	0.032		−0.006	
Vehicles per Driver	−0.004	−0.018	−0.006	−0.154
Income (000)	0.001	0.211	0.000	−0.255
Populational Density (000)	0.000	−0.017	0.000	0.116

Population density is positively associated with walking, even after accounting for trip distance. However, the relationship is modest. A 10% increase in density for all students in our sample would increase walk mode share by 1.2% But, before dismissing the effects of the built environment on school trip mode choice as negligible, it is critical to remember that the largest effect of the built environment is on distance to school. As density increases distance to school decreases ($r = -0.13$, $p < 0.01$). Therefore the effects of the built environment are being captured in the travel time variables.

Policy implications

Practitioners—both in planning and public health—have implemented programs to make communities more walkable and elevate levels of everyday physical activity. For example, grassroots efforts to encourage children to walk to school, e.g., Safe Routes to Schools, have converged with public health efforts to increase physical activity levels in children by having them walk to school, e.g., the Center for Disease Control's KidsWalk-to-School program. The net result has been increased funding to make schools more walkable destinations.

While these programs are key short and medium term strategies, neither affects the variable with the most influence on walking to school—trip lengths. If policymakers want to greatly increase the number of students walking to school, long-term strategies must encourage schools to be located near students. Addressing the spatial distribution of students and schools requires coordination of school, land use, and transportation planning. This coordination is essential because there is substantial new school construction and renovation of aging schools planned across the country. California, for example, passed over $25 billion in new school facilities construction measures in 2002 and 2004 (Coleman

2004). New Jersey is implementing nearly $9 billion in school construction (New Jersey Schools Construction Corporation 2005). Ohio recently began a 4-year, $10.5 billion program (Gurwitt 2004). This represents a major infrastructure investment and planners need to be a part of the process.

Pressure from smart growth advocates has already started the dialogue between school and land use planners. The Council of Educational Facility Planners International (CEFPI) and the US Environmental Protection Agency (EPA) (2004) authored a guide to advise facility planners on how their projects can fit with smart growth goals; EPA also commissioned a study of how school siting affects air quality and community design (Ewing and Greene 2003); and the National Trust for Historic Preservation (2003) documented the benefits of retaining small schools in existing areas rather than building on the fringe of communities. These efforts are important, but they often fail to critically evaluate how land use will affect school travel (Ewing and Greene 2003, is an exception). To address this gap, I consider how a land use and school planning policy emphasizing community schools, i.e., schools located within a neighborhood and easily accessible for most students, will impact children’s school travel. The previously developed model provides a means of testing how this policy could affect walk mode shares for the school trip.

Community schools

Until June 2004, the school siting guidelines of the CEFPI recommended one acre of land for every 100 students plus ten acres for an elementary school, 20 acres for a middle school, and 30 acres for a high school (CEFPI 1991). These guidelines were not context sensitive and required large campuses which, in many communities, could only be accommodated at the edge of town. These size requirements made it difficult for schools to be integrated into the community leading to long distances between home and school and low walking rates (Ewing and Greene 2003; National Trust for Historic Preservation 2003). New guidelines from CEFPI remove size standards allowing much more flexibility in school design (CEFPI 2004). In addition, the organization has encouraged educational facility planners to consider smart growth in their school designs (CEFPI and EPA 2004).

Advocates of smart growth and walking to school have encouraged districts to use this new flexibility to build community schools. The idea harks back to Perry’s (1939) vision of neighborhood units which contain an elementary school and ample play space. This type of design makes it possible for most children to live within walking distance of school. From a transportation perspective, community schools affect trip lengths by decreasing the distance from home to school. Therefore to understand how a shift to community schools might affect walking behavior, I created scenarios that specify each student’s distance to school. These scenarios estimated each student’s likelihood of walking given the trip length and then averaged over the sample to estimate the expected walk mode share. For example, one scenario estimates walk mode share if all students in the sample lived exactly 1.6 km (1 mile) from school. While this is unrealistic, it gives a good sense of the sensitivity of mode choice to distance.

With the current trip length distribution, the model predicts that 12% of students in the sample will walk to school. Changing the proportion of children walking to school requires large decreases in how far children travel to school. For example, if all children lived a 0.8 km (0.5 miles) from their school the model estimates that 34% would walk (Fig. 1). If students lived 1.6 km (1 mile) from their school, 19% would walk. These estimates assume

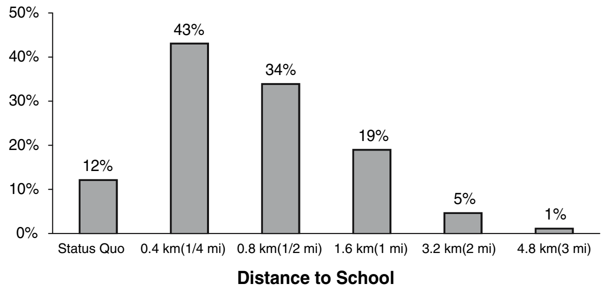

Fig. 1 Walk mode share: distance to school scenarios

all other factors, such as density, remain constant. In reality, places where community schools are possible also have higher-densities and lower auto ownership.

Using distance to school as a criterion in school siting and renovation decisions would give individual communities a chance to increase walking to school. Building schools near students—within 1–2 km—will result in more students walking and potentially in health benefits. Overall walking rates do not change if the maximum distance to school is 4 or 5 km. This places severe constraints on the size of the 'community' that can support a school.

A few simple calculations show the community schools model is only possible at moderate to high densities. A maximum walk distance of 1.6 km (1 mile) requires that all students live in an eight square kilometer area (3 mi^2); a maximum walk distance of 0.8 km (0.5 miles) equates to an area of two square kilometers (0.8 mi^2), assuming circular neighborhoods. If schools must draw from a larger area to get enough students, the model predicts no change in overall walk rates (because the majority of the students would live beyond a walkable distance). This finding means that community schools are only possible at moderate to high densities with large numbers of school-age children in small geographic areas. For example, in an area with 190 persons per square kilometer (500 persons/mi^2), only fifty elementary school-aged children would be expected to live within a 0.8 km (0.5 miles) radius of a school (assuming the U.S. average of 12% of the population being elementary school aged). That is hardly enough to support a one-room schoolhouse, nevermind a conventional elementary school. To create a viable elementary school of 300 students living within 1.6 km (1 mile) becomes possible at densities greater than 400 people per square kilometer (1,000 persons/mi^2). To have students live within a kilometer (0.5 miles) of their school, densities must be closer to 1,500.

The NHTS data show that 36% of households with children 6 to 15 live at densities of less than 400 people per square kilometer (1,000 persons/mi^2) and 64% live at densities of less than 1,500 people per square kilometer (4,000 persons/mi^2). This means that the community schools model is not a possibility in many existing communities. But, the scenarios do show that dense, new communities can plan around distance to school, and provide another argument for retrofitting schools in dense, urban locations rather than moving them. The information above also suggests that community schools work best at the elementary level. The smaller size of elementary schools allows smaller, more walkable, attendance zones.

Finally, planners must address the equity impacts of community schools. Many schools, particularly schools in low-income, urban areas, are already very segregated; and national statistics also reflect a trend toward resegregation of schools (Orfield 2001; Rickles et al. 2004). Assigning children to community schools may only exacerbate this problem in areas with high levels of residential segregation. Consider that the primary method for desegregating schools after the *Brown* decision was to switch children from their neighborhood school. While it could be argued that residential segregation should be tackled directly rather than making schools deal with it, planners and advocates for walking to school need to consider the equity impacts of community schools. In addition, because schools are spatially fixed and have long lives, decisions made about school siting today will have long-term effects. It may make sense to plan and build walkable schools, even if current levels of residential segregation preclude assigning today's students simply based on geography.

Conclusions

Analysis of the mode choice model identifies three key findings, which may be useful to researchers seeking to understand children's travel behavior and policymakers seeking to increase the proportion of children walking to school.

#1: Travel time, and therefore distance, has the strongest effect on mode choice. When choosing modes for the school trip, families largely appear to be minimizing their children's, and often their own, travel time. Children are also much more sensitive to walk travel time than auto, reflecting the fact that most people are not willing to walk long distances. The large impact of walk travel time on mode choice suggests that large numbers of students will walk to school only when they live close to school. Given that over 80% of students currently live more than 1.5 km from their schools, this is a significant obstacle to current policies designed to increase walking rates.

#2: Gender and race do not have large effects on mode choice. Basic averages and previous research have suggested that gender and race should have a strong effect on mode choice. The model shows that race has no effect on mode and that gender has a very weak effect, and one in the opposite direction of previous findings.

#3: Dense places encourage walking to school. Density has a weak positive association with walking to school. But density has its strongest effect on mode choice through trip distance. As density increases, children tend to live closer to their schools.

Long trip lengths are one of the primary reasons many students do not walk to school today. Programs addressing the safety of walking to school, such as SR2S, are key short-term strategies but they do not address the spatial distribution of students and schools. If policymakers want to substantially increase walking rates, the analyses and policy scenarios suggest that placing schools in neighborhoods is an effective policy option. The scenarios show that large increases in walk mode share could be achieved if most students lived within 1–2 km of their school. But there are some important caveats. First, community schools are only possible at moderate to high densities where there are enough students living in small geographic areas to fill classrooms. In addition, the community school model is best suited for elementary education because these schools are smaller and are better-suited to smaller areas. Finally, advocates for community schools have not discussed the potential equity impacts of this policy. In areas with high levels of residential segregation, community schools could increase school segregation.

These findings suggest a need for better integration of land use, transportation, and school planning. Including children's distance from school as a planning criterion could be an effective way to change community design and encourage walking. This coordination is most necessary in moderate and high-density areas and places designing large-scale