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Vehicle Emissions during Children's School Commuting: Impacts of Education Policy

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We explore how school policies influence the environmental impacts of school commutes. Our research is motivated by increased interest in school choice policies (in part because of the U.S. "No Child Left Behind" Act) and in reducing bus service to address recent budget shortfalls. Our analysis employs two samples of elementary-age children, age 5–12: a travel survey ($n = 1246$ respondents) and a school enrollment data set ($n = 19{,}655$ students). Multinomial logistic regression modeled the determinants of travel mode (automobile, school bus, and walking; $n = 803$ students meeting selection criteria). Travel distance has the single greatest effect on travel mode, though school choice, trip direction (to- or from-school), and grade play a role. Several policies were investigated quantitatively to predict the impact on school travel, vehicle emissions, and costs. We find that eliminating district-wide school choice (i.e., returning to a system with neighborhood schools only) would have significant impacts on transport modes and emissions, whereas in many cases proposed shifts in school choice and bus-provision policies would have only modest impacts. Policies such as school choice and school siting may conflict with the goal of increasing rates of active (i.e., nonmotorized) school commuting. Policies that curtail bus usage may reduce bus emissions but yield even larger increases in private-vehicle emissions. Our findings underscore the need to critically evaluate transportation-related environmental and health impacts of currently proposed changes in school policy.

Introduction

We explore the influence of school policy on the environmental impacts of children's school commuting. Children's school travel is increasingly of interest to researchers and policymakers for reasons that include health, safety, environmental impacts, traffic congestion, transportation costs, and parents' school-related travel time. In 2007, the U.S. population of youth, age 5–17 y, was 53 million (18% of the U.S. total), or larger than most nations. Children's commutes and their environmental impacts are influenced by factors ranging from local to national, and include decisions by households, governments, and private organizations.

Busing is often a significant and contested portion of school district budgets, especially with declining budgets and rising or volatile fuel prices (*1*). Several federal (*2*) and state (*3, 4*) initiatives, including the Safe Routes to School program (SRTS; $612 million over 5 years) of the U.S. Transportation Bill (*5, 6*), aim to raise children's daily activity levels and improve health by increasing rates of walking to school (*7*). Despite the amount of money being spent, there has not been comprehensive evaluation of the SRTS program (*8*); robust evidence that SRTS-type investments significantly shift behaviors or benefit children's health is lacking. Other major thrusts for improving environmental and health impacts of school travel include reducing bus emissions (*9–13*), idling (*14*), and self-pollution (*15–17*).

This article evaluates institutional factors affecting public and private vehicle activity (i.e., vehicle-kilometers traveled) for children's school commutes. Literature reviews on children's commute patterns are available elsewhere (*18–20*). Traditionally, children attended the school closest to home ("neighborhood school"). In contrast, school choice allows attendance at a non-neighborhood ("magnet") school. School choice programs are significantly more common today than 20 years ago (*21*). Their prevalence is expected to increase, and the 2002 "No Child Left Behind" Act encourages school choice (*22*). While parents generally support school choice (*23–25*), few studies have quantified its effect on school transportation. An analysis of national data found that school choice tends to increase commute distance and decrease walking rates (*26*). A recent investigation, partially by authors of the current manuscript, surveyed parents to determine how they choose a school and a commute mode for their child and developed a multinomial logit travel model (*19*).

This investigation adds to this literature by exploring how school policies influence the environmental impacts of school commutes. We first use survey results to develop a statistical model of children's commute mode and apply that model to a citywide sample. Then, we test the impact of school choice policy on childrens commutes, using routing software and the model MOBILE6 to estimate emissions for school buses and private vehicles.

Methods

We describe here (1) our survey-derived multinomial logit regression model of school commute travel mode (automobile, school bus, walking), (2) our approach for estimating automobile- and bus-routing and emissions, and (3) the policy scenarios considered. To explore the potential impact of school choice, we selected a study location (St. Paul, MN; population 287,000) with an extensive school choice system already in place. Because school choice may become more widespread in the future, findings for our study location may be indicative of future patterns for an increasing number of U.S. urban areas.

Logit Regression Model. Logit regression models predict the relative likelihood of an outcome—for example, the odds that a child's commute mode would be walking rather than automobile. We derived our model from a 22-question school

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travel survey administered to parents of elementary-age children in St. Paul Public Schools (SPPS). Information about the survey, including descriptive statistics of the results and an evaluation of the representativeness of respondents, is available elsewhere (*19, 20*). Survey questions included home and school locations, grade, race, gender, and to- and from-school commute mode (see Supporting Information). Respondents indicated the number of days last week that their child with the most recent birthday traveled to- and from-school via private vehicle, school bus, walking, bicycling, or another mode. We combined walking and bicycling because of low bicycling counts (0.9% of student-trips), and excluded from the model "other" modes (0.08% of student-trips) for the same reason. The regression model predicts students' dominant school travel mode among automobile, bus, and walk. Results suggest that for the comparison investigated here, this approximation (i.e., evaluating dominant travel mode only) is appropriate: children use one mode of travel for 77% of to-school trips, 80% of from-school trips, and 60% of all weekly trips. A minority of students (16%) switch dominant mode between to- and from-school trips.

In late May 2007, surveys were mailed to 6000 randomly selected households containing a child attending a St. Paul Public Schools (SPPS), grade K−8. All households received an English survey; a Spanish, Hmong, or Somali version was added where indicated by SPPS records of primary home language. Reminder postcards (English; non-English) followed one week later. The response rate was 21% ($n = 1264$). We investigated nonresponse bias in the outcome variable by comparing modal splits by distance to school among survey respondents versus national estimates; we found similar rates of walking and motorized travel for trips of the same distance (*27*). Assessment of nonresponse by demographic characteristics found that wealthier and whiter households were more likely to respond to the survey, but the sample included substantial responses from minority groups (9% African-American, 11% Asian, 8% Latino) and lower income families (25% from households with incomes less than $40,000). To help address nonresponse bias, survey weights were applied to match the city income and race profile. The diversity of respondents, our ability to weight the sample to reflect the population demographics, and similarities between our data and national data suggest that results presented here reflect true attributes of the system we studied, and are not spurious findings attributable only to the low response rate; further discussion is below.

We excluded the 51 (4%) surveys from middle school students (grades 7−8), 296 (23%) incomplete surveys, and 114 (9%) surveys from parents residing outside St. Paul, yielding 803 valid responses used in our model. We use only elementary school students (K−6) because of different catchment patterns and transportation rules for middle school students. We calculated the shortest-route network distance between residence and school using ArcGIS 9.1. Logit regression models estimate the relative likelihood that a student would use a specific travel mode (dependent variable), based on attributes such as commute distance (independent variables; see below).

After developing the logit model, we then applied it to all elementary-age SPPS children to estimate travel modes. Data on all 19,655 elementary-age students in SPPS were acquired in March 2008 through a research agreement with the school district. We excluded the 1046 (5%) of students enrolled in SPPS yet living outside district boundaries, yielding 18,609 children considered in analyses below. Reasons for removing those 5% of students (likely, children who previously lived in St. Paul, and remained as a SPPS student after moving nearby) include that busing is only available for students residing within the SPPS boundaries, and that the dominant travel mode for this 5% is automobile (84%). Policies evaluated here would not directly alter mode choice for those families.

More information is available about the 803 survey respondents (based on the 22-question survey) than is available for the 18,609 SPPS children (based on the district's records: grade, race, gender, home-school commute distance). A detailed logit model that describes travel patterns for survey respondents only is available elsewhere (*19, 20*). The model generated here uses only those variables available for all SPPS students, thereby allowing direct application of the model to the district-wide sample. For each child, we randomly assigned a commute mode based on the probabilities estimated by the logit model. Model uncertainty is estimated by comparing predictions against the 803 survey responses. We explored the robustness of the findings to perturbations in input data by generating separate models for six subsets of the data (three random subsets, three pseudorandom subsets), as given below.

Vehicle Routing. We estimated shortest network-distance travel routes for automobile or walking using ArcGIS, given trip origin and destination. Bus routes for each school were generated using ArcLogistics optimization, employing the following constraints: (1) a student's bus stop can be no more than 0.33 miles (0.54 km) from his/her home, (2) all buses start at the First Student bus depot (Como Avenue, St. Paul) and must arrive at the school at least 10 min before the school start time, (3) loading time is 30 s per stop, (4) maximum trip length is 1 h, (5) maximum seating capacity is 77 students, and (6) buses may drop-off students at the school only once, at the end of the route. These constraints reflect current SPPS bus practices. The two options for optimizing bus routes and number of buses are time and distance; both options yield identical or very similar results for situations investigated here.

Emissions. We employed the U.S. Environmental Protection Agency's MOBILE6 model (www.epa.gov/otaq/mobile.htm) to estimate emissions from private vehicles and school buses for five pollutants: CO, CO_2, PM_{10}, NO_x, and volatile organic compounds (VOCs). MOBILE6 separately provides running emissions during vehicle operation and nonrunning emissions such as cold-start, hot-soak, and diurnal breathing losses. Surveyed parents indicated whether school commutes are sole- or multi-purpose trips. For sole-purpose trips, we estimate emissions as one round-trip between home and school. For multi-purpose trips (i.e., trip chaining), we estimated attributable emissions as one-half of a one-way trip between home and school.

To explore whether fleet-wide average emission factors from MOBILE6 are appropriate for vehicles employed by our subpopulation (i.e., families with elementary-age children), we considered the fuel economy (www.fueleconomy.gov; based on vehicle make, model, and year) and vehicle age for a random sample of 165 survey respondents. The resulting fuel economy values (mean 20.55 mpg; standard deviation 4.21 mpg) is comparable to the MOBILE6 fleet-wide average (20.4 mpg). Similar findings apply to vehicle age (median [mean] age is 8 [8.1] years for survey respondents, and 8 [8.3] years for the MOBILE6 database), suggesting that MOBILE6 provides reasonable estimates for questions considered here.

Policy Scenarios. To explore environmental impacts of school policy choices, we investigated the following five policy scenarios.

(1) *Current.* In the base case, students are modeled as attending the school that they actually attend. Among surveyed children, 65% attend a magnet school, 35% attend a neighborhood school. Among all SPPS students, the divide is similar: 68% magnet, 32% neighborhood. Only 24% of surveyed children (20% of SPPS students) attend the school that is closest to their residence.

TABLE 1. Multinomial Logistic Regression Model

variable	bus[a] coef.	bus[a] std. error	bus[a] $P > \|z\|$	bus[a] odds	walk[a] coef.	walk[a] std. error	walk[a] $P > \|z\|$	walk[a] odds
intercept	–1.269	0.558	0.023		1.101	0.467	0.018	
trip direction, to-school (0 = from-school)	–0.195	0.133	0.145	0.823	–0.497	0.224	0.027	0.609
school type, magnet (0 = neighborhood)	0.939	0.145	0	2.56	–0.022	0.230	0.924	0.978
race, white (0 = nonwhite)	–1.15	0.170	0	0.318	0.052	0.287	0.857	1.053
school commute travel distance								
<0.4 km	0				0			
0.4–0.8 km	0.379	0.643	0.556	1.46	0.339	0.397	0.393	1.40
0.8–1.2 km	0.292	0.611	0.633	1.34	–1.83	0.399	0	0.161
1.2–1.6 km	1.73	0.573	0.003	5.64	–1.77	0.414	0	0.171
1.6–2.4 km	1.85	0.551	0.001	6.37	–3.27	0.479	0	0.038
2.4–3.2 km	2.47	0.559	0	11.8	–4.30	0.815	0	0.014
3.2–4.8 km	2.28	0.546	0	9.76	–5.60	1.10	0	0.004
>4.8 km	2.74	0.540	0	15.5	–4.27	0.594	0	0.014
child's grade in school								
kindergarten	0				0			
1	0.330	0.204	0.106	1.39	0.032	0.376	0.932	1.03
2	–0.190	0.216	0.379	0.827	0.339	0.360	0.347	1.40
3	0.568	0.229	0.013	1.77	–0.776	0.458	0.090	0.460
4	0.233	0.259	0.368	1.26	0.377	0.402	0.348	1.46
5	0.757	0.262	0.004	2.13	0.710	0.438	0.105	2.04
6	1.66	0.287	0	5.27	1.66	0.440	0	5.27

[a] Automobile is the reference mode. Nagelkerke pseudo-R^2: 0.54. Correct prediction rate: 75%. Number of observations: 803. Model is statistically significant at $p < 0.001$.

(2) *Random*. Each student is assigned to a random school in the district. This scenario represents the logical extreme of school choice: a situation in which location or travel distance does not matter.

(3) *Neighborhood Only*. Non-neighborhood schools are disallowed. Each student attending a non-neighborhood school was reassigned to the neighborhood school closest to his/her residence. This scenario represents the minimum necessary commute for connecting students and schools.

(4) *Regional Choice*. The district is subdivided into three equally sized zones (West, East, South); parents choosing a non-neighborhood school must select from among schools in their zone. These zones were selected based on conversations with SPPS staff to mimic most-likely zones if this policy were enacted. Currently, 67% of students attend a school inside their zone and the rest (33%) cross into a new zone during their school commute. For this scenario, the former group does not change schools; the latter group switches to a randomly selected within-zone school. At the suggestion of SPPS staff (*28*), we maintained five district-wide schools as exceptions to the within-zone requirement (Adams Spanish Immersion, Benjamin Mays, Capitol Hill, French Immersion, and Museum Magnet); students are allowed to cross into a new zone to attend one of these five schools.

(5) *Increased Walking*. All children within a certain radius of their school must commute via walking. This scenario, which reflects an extreme case of SRTS, mirrors the current scenario (i.e., we did not modify which school each student attends). The radii selected are 1 mile (1.6 km), with 0.5 miles (0.8 km) as a sensitivity analysis. Those two distances reflect both district policy that bus service is only guaranteed for students commuting more than 1 mile, and our observation based on our data, consistent with available literature, that walking rates are much greater for commute distance less than 0.5 mile than for greater than 0.5 mile.

For each policy scenario, our analyses included the following steps. We started with the base case (current scenario); modified the schools attended according to the description above; used the logit model to determine travel mode for each child; for the increased walking scenario, reassigned appropriate students to walking; used ArcLogistics to determine school bus routes; and lastly calculated vehicle emissions and costs. Costs per vehicle-km are \$4.46 for SPPS buses (*29*) and \$0.34 for private vehicles (*30*).

Results

Logit Model. The logistic regression model estimates the odds of bus and walk relative to the reference mode (automobile). The model has a pseudo-R^2 of 0.54 and correctly predicts travel mode for 75% of the students. Given the small number of variables included in the model and the stochastic nature of travel-mode prediction (i.e., randomly selecting a mode based on the logit-calculated probabilities), the model exhibits good agreement with input data. For the 803 survey respondents, the proportion of students busing, driving, and walking are 74%, 13%, and 13%, respectively, in the model predictions, and 63%, 25%, and 13%, respectively, in the survey data. Predictions are more accurate for busing and walking (78% and 71%, respectively, of predictions are correct) than for driving (58% of predictions are correct).

Logit results are in Table 1. For example, for walking, at a commute distance of 0.8−1.2 km, the regression coefficient is −1.83 and the odds ratio is 0.161. The sign of the regression coefficient (negative) indicates that, all else being equal, the likelihood that a student will walk rather than be driven is lower for that commute distance (0.8−1.2 km) than for the reference distance (<0.4 km). The odds that a student will walk rather than be driven (here and elsewhere, logit results are relative to reference mode [automobile]) at 0.8−1.2 km are 16.1% of the odds at the reference distance. At reference conditions (from-school trip, neighborhood school, travel distance less than 0.4 km, grade kindergarten, race nonwhite), the modeled likelihood of walking, busing, and driving are 70%, 7%, and 23%, respectively.

Some trends in Table 1 are nonmonotonic. In some cases, those trends involve statistical p values that indicate coefficients are not statistically significant. In other cases, the trends are statistically significant but still suggest a consistent

TABLE 2. Estimated Daily Travel by Scenario

	current			random	neighborhood only	regional choice	increased walking
	magnet	neighborhood	total				
students	12,694	5915	18,609	18,609	18,609	18,609	18,609
travel distance							
mean (km)	4.6	2.6	4.0	7.1	0.8	4.0	4.0
median (km)	4.1	1.7	3.4	6.8	0.8	3.4	3.4
dominant travel mode to-school							
auto (%)	15	32	21	16	31	27	12
bus (%)	77	46	67	82	28	60	60
walk (%)	7	22	12	2	41	13	28
dominant travel mode from-school							
auto (%)	13	26	17	14	25	23	10
bus (%)	79	47	69	84	27	62	62
walk (%)	9	26	14	2	48	16	28
total district passenger travel to-school[a]							
auto (km)	7003	4133	11,136	20,250	5064	16,360	9724
walk (km)	1029	1027	2056	832	4691	2030	4902
bus (vehicle-km)	2448	499	2947	~5000	146	2090	3005
bus (passenger-km)	50,280	10,260	60,540	~110,000	5535	55,770	59,110
total district passenger travel from-school[a]							
auto (km)	5862	3519	9381	17,310	4176	14,030	8224
walk (km)	1211	1240	2451	1137	5613	2546	5032
bus (vehicle-km)	2494	519	3013	~5000	144	2157	3074
bus (passenger-km)	51,240	10,660	61,900	~110,000	5501	57,590	60,480

[a] Sum of student travel distance by mode. For auto, vehicle-km is equal to passenger-km.

finding (e.g., busing odds ratios for 2.4–3.2 km, 3.2–4.8 km, and >4.8 km are nonmonotonic, but all three values indicate that busing is approximately 1 order of magnitude more likely than the reference mode). These nonmonotonic trends emphasize the importance of using categorical variables (Table 1) rather than linear regression.

Odds of walking decline rapidly at longer travel distances: for travel distances greater than 1.6 km (1 mile), the odds of walking are nearly zero (less than 2% of the odds of being driven). The reverse holds for busing: all else being equal, the odds that a student will bus are 6–16 times greater for distances greater than 1.6 km than for the reference distance, likely mirroring the SPPS busing policy. The odds of busing are not statistically different at distances less than 1.2 km than at the reference distance.

Odds of walking to-school are 61% of the odds of walking from-school, a finding consistent with previous research (*31*, *32*). Busing appears to follow a similar trend (lower odds to-school than from-school), but at a 95% confidence interval the difference is not statistically significant.

Odds of busing are 2.6× greater for magnet students than neighborhood students. In the logit model, school type is not a statistically significant predictor of walking odds. However, actual and logit-predicted walking rates differ by school type, because on average travel distance is greater (and therefore walking rates are lower) for magnet than for neighborhood schools. Busing and walking are generally more likely among older children than kindergarteners. Finally, odds of busing are 3× lower for whites as for nonwhites. Race is not a significant predictor of walking odds.

To explore the robustness of the model to perturbations in input data, we generated analogous models as Table 1, using subsets of the input data: three subsets were random (in each case, employing 2/3 of the data [$n = 535$]) and three subsets were pseudorandom (street name of home residence begins with a letter between "A" and "M" [$n = 548$]; school name begins with a letter between "A" and "M" [$n = 647$]; number of household vehicles = 2 [$n = 480$]). Model coefficients are similar for these six models as for the main model. Correct prediction rates and pseudo-R^2 values are consistent for the six models (71%–77% and 0.52–0.61, respectively) as for the main model (75% and 0.54, respectively). These findings suggest that the logit model is reasonably robust to perturbations in input data.

Scenarios. Table 2 presents estimated travel demand by mode for each scenario. Rates and distances of active travel per scenario are shown in Figure 1. Emission estimates are summarized in Figure 2. Results per scenario reflect shifts in travel distances and modes, and differences in emissions for automobiles versus buses.

Current. The median travel distance is 3.4 km. Relative to magnet schools, neighborhood schools have ~2× shorter average travel distance, ~2× lower busing rates, ~2× higher automobile rates, and ~3× higher walking rates. The percent of students living within 1 mile of school is ~2× greater for neighborhood schools than for magnet schools (46% versus 19%).

Random. Relative to the current scenario, average commute distance nearly doubles (from 4.0 to 7.1 km). Walking rates decrease dramatically (from ~13% to 2%) and the total distance walked decreases 56%. Automobile usage rates decrease, but because of the longer commute distance, total automotive travel distance nearly doubles. Busing rates increase, and busing passenger-distance nearly doubles. This scenario represents a bounding exercise only; we did not estimate emissions or costs for this case.

Neighborhood Only. The neighborhood only scenario (i.e., eliminating school choice) reduces average travel distance 4- to 5-fold. Walking rates increase 3- to 4-fold, and distance walked more than doubles. Automobile rates increase, but owing to shorter commutes, distance traveled by automobile is more than cut in half. Busing rate drops by more than half and busing distance declines by more than an order of magnitude. Emissions are 3–8 times lower for the neighborhood-only scenario as for the current scenario.

Regional Choice. Here, the 33% of students attending a school outside their region were modeled as switching schools. Median and mean travel distance are nearly unchanged, as are walking rate and walking distance. Distance bused decreases ~7%, but automobile usage increases, with distance traveled by automobile increasing ~50%. The net emission impact is a 13% reduction for NO_x and a 4–45% increase for the remaining pollutants. The fraction of emissions coming from buses decreases. The bus

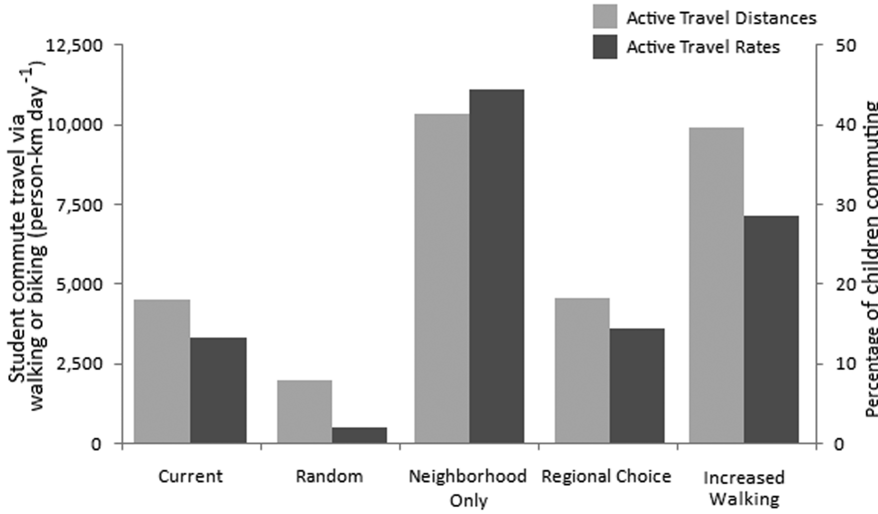

FIGURE 1. Student commuting via active travel per scenario.

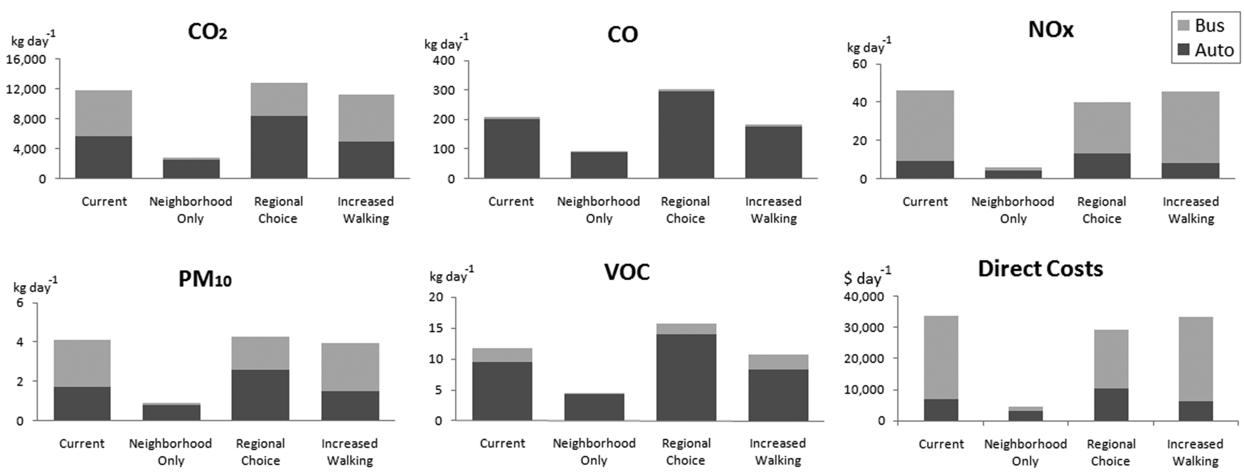

FIGURE 2. Emissions (kg day^{-1}) and direct costs ($ day^{-1}) per scenario.

load factor, which is a measure of the efficiency with which busing service can be offered, increases ~30% (average passenger-km per vehicle-km: 21 for current, 27 for regional choice).

Increased Walking. Here the 27% of students living within 1 mile of their school are assigned to walking. Walking rate and walking distance more than double. Automobile usage declines 8 percentage points (from 19% to 11%), and automobile travel distance declines ~13%. Busing rate decreases 7 percentage points, but total distance bused decreases only ~2% because few people living within 1 mile from school are currently bused and because shifting those students' travel mode does not significantly alter bus routes. Emission decreases are 1−12% among pollutants.

Figure 2 provides estimates of direct costs for transportation. The regional choice scenario reduces bus costs but increases costs for private automobiles; analogous results hold for emissions. Travel costs are more than 7 times greater for current school-choice as for neighborhood-only. As discussed below, cost estimates are sensitive to the use of local versus national data (see Table 3).

TABLE 3. Transportation Costs by Scenario, Using Local versus National Data

scenario	using local costs[a]	using national costs[a]
current	$33,500 (79%)	$17,400 (60%)
neighborhood only	$4,400 (29%)	$3,600 (14%)
regional choice	$29,200 (65%)	$17,700 (42%)
increased walking	$33,200 (82%)	$16,700 (64%)

[a] Dollar amounts indicate combined (bus + automobile) direct costs per day. Values in parentheses indicate percent attributable to bus costs.

Discussion

Our results indicate that school-assignment policy can have a large effect on environmental impacts of school commute travel. Relative to the neighborhood-only (i.e., non-school-choice) scenario, emissions of CO_2 and of the four urban air pollutants studied here are 4−7 times greater for regional school-choice and 3−8 times greater for current school-choice. Transportation costs and rates of active commute travel (walking/biking) are 8 times greater and 3 times lower, respectively, for the current scenario as for the neighborhood only scenario.

Generally, institutional decisions such as the case considered here (school choice) can have significant impacts on an organization's greenhouse gas emissions. Those impacts are often not fully quantified prior to the decision, in part reflecting the technical challenges involved in such comparisons and in part reflecting that environmental considerations are typically a secondary concern in such decisions. Our investigation highlights a case in which choices having little or no explicit connection with the environment end up having significant environmental consequences, and also one in which shifts in activity level (vehicle-kilometers traveled) have a strong influence on CO_2 and other vehicle emissions.

The emissions reductions for the increased walking (SRTS) and the regional choice scenarios are surprisingly modest. Because many people in SPPS choose to attend a school that is farther than they wish to walk (i.e., commute distance greater than 1 mile), for our study location efforts to improve walking safety (SRTS) are projected to have only minor impacts on the overall system in terms of emissions. (However, as highlighted above and in Figure 1, the increased walking scenario exhibits notable increases in walking rates relative to current.) This finding may or may not hold in locations without school choice. In the regional choice scenario, the 33% of students changing school receive a random new school in their choice region; the new school is not necessarily closer than their previous school. Reductions in bus travel are offset by increases in automobile travel; for some pollutants, increases in automobile emissions more than offset reductions in bus emissions. Both findings suggest that these policies may not produce the hoped-for reduction in costs and emissions, especially when both public (bus) and private (automobile) costs and emissions are analyzed.

Because we focus on environmental impacts, we do not evaluate here the advantages cited by school choice advocates (e.g., increased racial and socioeconomic integration, parental choice, rise in magnet and other specialized learning programs, increased overall educational quality owing to competition among schools), nor whether the disadvantages (e.g., additional commuting; additional administrative burden) outweigh potential advantages. Another important issue not investigated here is siting policies for new schools. School districts often must choose between investing resources in existing schools (upkeep and maintenance) versus constructing a new school near current population centers or in "green fields" farther from population centers. Our investigation highlights potential environmental, health, and economic benefits of locating schools relatively closer to students' homes.

School choice can dramatically reduce active travel and the potential impacts of SRTS-type interventions. With widespread interest and investment in SRTS and school-choice, more work is needed to evaluate whether and how those two goals can work together.

All studies have limitations and uncertainties. Here, we use a survey with a low response rate (21%) to explore the possible impact of changes in school policy. We implicitly assume that respondents were truthful, that the preferences of nonrespondents do not differ significantly from respondents (other than via demographic differences, as accounted for using weighting factors), and that future actions would be predicted by the logit model developed here. Our investigation evaluates costs and emissions from school commutes only, and does not consider issues such as emission-reduction technologies (e.g., electric vehicles; diesel retrofitting) or changes in residential or workplace locations.

We hypothesize that school travel surveys may generally receive low response rates because of safety concerns about revealing children's travel patterns and locations, even to university researchers. For example, an Australian study of school travel reported a 27% response rate among parents of 5−6 year olds and 44% among parents of 10−12 year olds; responses were lower in disadvantaged areas than in other areas (*33*). While classic texts on survey methodology highlight the importance of high response rates (*34, 35*), a recent literature review emphasized that "there is little empirical support for the notion that low response rate surveys de facto produce estimates with high nonresponse bias" and that "nonresponse rate alone is a weak predictor of nonresponse bias" (*36*). Recent analyses and meta-analyses find that lower response rates (for example, 61% versus 36% (*37*), and 50% versus 25% (*38*)) generally do not alter survey results significantly.

An important finding, and a potential source of uncertainty for extrapolation to other locations, is that the use of local rather than national data may influence results. For example, school bus costs are higher in St. Paul ($4.46 km^{-1}) than the national average ($1.76 km^{-1}) (*39*), owing in part to the contract-based bus service used in SPPS. As a result, among the four scenarios considered in Figure 2, the third-most-expensive option (regional choice) becomes the first-most-expensive option if one employs national rather than local bus-cost data (Table 3). The reason for this shift in ranking is that regional choice involves the highest automobile costs of the four scenarios; automobiles are less than half of the total cost if using local data, but more than half if using national data.

Child travel is uniquely influenced by decisions of others, including parents and school boards. Research presented here can help inform education policies that maximize learning opportunities, provide health benefits, and improve safety, while reducing transportation costs, environmental impacts, congestion, and parent's school-related travel. Two of the policies we tested yielded only modest impacts to school commuting and its environmental impacts, while the third policy yielded significant shifts in travel and its environmental impacts. As mentioned above, few tools are currently available to help school districts explore transportation impacts of school policy. We are in early stages of developing a decision support tool, freely available online (http://schooltransport.hhh.umn.edu/), which we hope will help address this gap. This online tool is presently applied to St. Paul only, but with basic information (e.g., names and locations of schools) could be extended to evaluate other locations.

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Supporting Information Available

The survey administered to parents in St. Paul. This material is available free of charge via the Internet at http://pubs.acs.org.

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