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Edited by Gregory K. Ingram and Daphne A. Kenyon

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Transport Costs of School Choice

Kevin J. Krizek, Elizabeth J. Wilson,
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School choice refers to a policy that allows students to attend a school other than the one nearest to their home.[1] Relative to attending neighborhood schools, school choice can increase travel distances and decrease rates of walking or biking to school, potentially reduce total physical activity, increase transport costs and time, and increase emissions of urban air pollution and greenhouse gases. This chapter explores the transport costs of school choice, first by reviewing the literature, second through a survey on school transportation, and third through a modeling application. The primary data collection and research were conducted with St. Paul Public Schools (SPPS) in St. Paul, Minnesota. The data gathered there aided in the construction of a detailed case and model to evaluate school choice. This research was guided by the following questions: (1) How does school choice influence the choice of travel mode to and from school? (2) How does school choice change the corresponding costs (public and private) and associated environmental emissions?

This work was made possible by support from the Center for Transportation Studies at the University of Minnesota. Steve Schellenberg at the St. Paul Public School District was an invaluable help, and Noreen McDonald provided keen insights. Research assistants Emily Polak, Katie Meyer, and Santosh Rajangam contributed substantively to the project.

1. School choice is sometimes referred to as "open enrollment" and may include options such as magnet schools and alternative schools. Throughout this chapter, the term *school choice* is used to encompass all of these options.

Motivation for This Research

School choice offers many potential benefits. These could include increased racial and socioeconomic integration, enhanced parental choice, and the ability of students to attend magnet and other specialized learning programs focused on science, language, or the arts. Proponents of school choice also argue that overall educational quality is improved due to competition among schools. The purpose of this research was not to support or dispute these claims. The availability of school choice does, however, carry some costs and alters patterns of school travel and transportation. This chapter focuses on identifying changes in school transportation resulting from school choice and accounting for associated changes in transport costs and the associated environmental emissions. Estimates of the responsiveness of school transport to school choice can be thought of as measures of elasticity.

In most cases, choosing to attend a school other than a neighborhood school incurs additional travel. The transportation literature refers to a similar issue as "excess commuting,"[2] defined as additional journey-to-work travel and represented by the difference between the actual average commute and the smallest possible average commute, given the spatial configuration of workplace and residential sites. This concept can be applied to school travel as well. Several reasons help explain why this topic is receiving increased attention. First, school travel relates to children and their education—perennially critical topics—and the rise in school choice in many districts underscores that this is an important topic. Second, the childhood obesity epidemic, especially in the United States, is growing rapidly, and increased travel distances tend to preclude walking or biking. Third, unlike excess commuting, which is strictly a reflection of market forces, excess school commuting is permitted via school district policies (or national policies in the U.K.). It is controlled by school districts, and tight school budgets are forcing a reexamination of all costs, including transportation.

The transport costs of school choice have increasingly generated much debate and controversy, owing primarily to three categories of costs: (1) the direct monetary costs to the school district, usually in the form of busing; (2) the associated environmental costs to society associated with school travel; and (3) the indirect costs to parents and the community. The first category is the one most easily quantified, as most districts have a delineated budget for busing costs. The size of such budgets varies considerably based on several factors that include, but are not limited to, average residential distances (transport costs are usually

2. For example, employees may bypass employment opportunities closer to home, even with the same employer, in favor of other workplace environments; residents may bypass the nearest grocery store to better match their food or shopping environment preferences.

greater as residential densities decline), school transport policy parameters (established maximum walking distances, the provision of transport service to nonneighborhood schools, routing and transport management policies), and attention to caring for students with disabilities.

For example, in two city school districts with roughly the same number of students and the same area, Minneapolis and St. Paul, buses traveled more than twice as many miles per day in Minneapolis than in St. Paul in 2008 (10.6 versus 4.8 million miles per year). This was due in part to different school district policies regarding pickup distance and providing transportation to charter schools. Minneapolis provided bus service to children living 0.5 mile or more from school, while St. Paul provided service for students living over one mile from school.[3] Additionally, while both districts were legally required to offer transportation options for charter schools in the district, Minneapolis did so for a much greater number of schools.[4] Also, the St. Paul public school district prides itself on the efficiency of its transportation system and is consistently highly ranked in *School Bus Fleet*'s annual survey. For example, the 2010 survey estimated that Minneapolis's school transport cost per pupil was $779 per year, compared to St. Paul's cost of $417 per year (the average national cost per pupil was $570) (St. Paul Public Schools Transportation Department n.d.).

The salience of the topic of school transport is highlighted by the number of school districts wrestling with transportation design and cost, the number of parents concerned about education and access, and the rapid rise of academic reports and papers on the subject. This chapter aims to address the relationship between school choice and transport costs (public and private) and the associated environmental emissions. Table 8.1 presents the range of direct and indirect costs of school transportation. While the first-order effects could conceivably be more directly measured, often the second-order effects also have large societal impacts. For example, the "chauffeuring" of children by adults to schools that do not offer busing impacts the travel patterns of the adults and potentially affects their work start times or other activities.

Identifying the extent of the various "excess" or "other" costs is one dimension of this issue. Drawing connections between the extent of school choice (e.g., how many students take advantage of choice) and the corresponding transport costs are other dimensions.

3. This has since changed, and St. Paul now provides bus service for students living over 0.5 mile from school.

4. By contrast, St. Paul adopted a policy allowing charter schools to use St. Paul school buses, but not between 7 and 9 a.m. If a charter school wanted to use these buses, its start time would have to have been 9:45 or 10 a.m., unacceptable to most parents. Most charter schools chose to either contract with a bus company on their own or not offer bus service.

Table 8.1
Transport-Specific Costs of Excess School Travel

Primary Effects	Possible or Example Scenario
Longer travel distances	More auto use and corresponding fuel needed; time spent in commuting
Emissions	Increased emissions from either autos or buses; effects on passengers, residents, and the environment
Physical activity	Decreased opportunity to walk or bike to school because of increased travel distance
District busing costs	Increased per student bus miles and coverage area; increased costs for buses (e.g., fuel, maintenance)
Safety	Increased congestion around schools during drop-off and pickup, exacerbating pedestrian-auto interactions and resulting in additional safety considerations
Secondary Effects	**Possible or Example Scenario**
Parental convenience	Increased scheduling burden because of school drop-off and pickup
Parental travel patterns	More auto-oriented travel
Vehicle ownership	Second auto needed for additional school travel
Traffic congestion	Increased road congestion and decreased transportation flexibility resulting from locked-in start and end times
Gender-specific effects	Gender bias in school choice travel patterns and impacts because mothers are more likely to drive children to school

Existing Knowledge

The attention to, knowledge of, and literature about school travel, school choice, and the relationship between the two are growing rapidly. The research focusing on school choice is mature and relatively developed (Powers and Cookson 1999). Various dimensions are covered elsewhere (Gorard, Fitz, and Taylor 2001), including its history (Forman 2004) and its relationship to parental satisfaction (Goldring and Shapira 1993).

What amounted to a handful of studies focusing on school transportation in the early 2000s has now grown to almost a hundred research reports and papers. The orientation and primary research question of these studies vary considerably. Topics include literature about youth travel and the connection to school transportation (Krizek, Birnbaum, and Levinson 2004); policies related to school travel among parents or school leaders (Eyler et al. 2008; Mathews et al. 2010); and the role of urban form (Schlossberg et al. 2006). The literature also includes statistics on the decline in the number of students who walk or bike and the reasons for this (Ham, Martin, and Kohl 2008; McDonald 2007; McMillan 2005). Other studies focus on the impact of Safe Routes to School (SRTS) programs (Boarnet, Anderson et al. 2005; Boarnet, Day et al. 2005; Chriqui et al. 2012) or the relationship to children's physical activity (Panter et al. 2011). Some research concentrates strictly on the impact of school closures (Müller, Tscharaktschiew, and Haase 2008) or the environmental emissions of school travel (Singleton 2013). These (and others) are all important studies; however, they fail to get at one acute dimension of the literature: the relationship between school choice and transport costs. That relationship is the focus of this chapter.

Table 8.2 provides an overview of studies and other cases (some are "back of the envelope" calculations) that have focused on (1) the extent of school choice in various settings; and (2) the implications for transportation, travel behavior, or related costs.

These studies address different dimensions of the school choice–transport issue. While they are difficult to compare directly, they provide useful analytical

Table 8.2
Studies and Other Cases Discussing the Relationship Between School Choice and Transport

Setting and Citation	Scope of Study	Methods, Analysis, or Approach	Conclusions
Eugene, Oregon (Yang, Abbott, and Schlossberg 2012)	2,071 (37%) of 6,000 students in the district exercise school choice (among 26 elementary schools).	• GIS data of all students and a survey sample of 1,123 families. • Travel distance is 1.9 km for neighborhood school students and 4.15 km for school choice students.	School choice student travel is more than double that of neighborhood school students.
Oakland, California (Makarewicz 2013)	Interviews with 70 parents.	• 49% of students attend neighborhood school.	Within the group of students who attend charter schools, 40% are driven, 1.6 times the percentage of students who attend neighborhood schools.
Boulder Valley, Colorado[a]	10,455 (36%) students of 28,986 avail themselves of school choice.	• 81,634 miles of school travel daily. SOV rates range from 55% to 75% for fully open-enrollment. • 40% of about 30,000 kids = 12,000 SOVs, or 24,000 SOV trips per day. • 80,000 ÷ 30,000 kids = 2.66 miles per trip.[b] • 6 miles per day × 24,000 = 144,000 miles per day; multiply that by 170 school days.	24,480,000 miles per year of SOV school travel. Assuming one-third of this is attributed to school choice, 8,160,000 miles per year of SOV travel.

Table 8.2
(continued)

Setting and Citation	Scope of Study	Methods, Analysis, or Approach	Conclusions
England (Van Ristell et al. 2013)	Random sample of 69,910 students from a census of about 7.5 million students.	• 42.5% of students attend the school closest to home. • Logit modeling of current behavior and then replacing it with the assumption that school choice is removed.	Assuming students go to the nearest school, VMT falls by 1% for car use and 10% for bus use. Mode choice: car use falls from 32% to 22%, bus use falls from 12% to 7%, and NMT rises 17%.
Boston, Massachusetts (Boston Choice 2012)	One neighborhood.	• 1,193 K–8 students in one Boston neighborhood travel to 64 different schools.	1,173 miles traveled per day.
Denver, Colorado (Teske, Fitzpatrick, and O'Brien 2009)	600 parents: 300 in Denver and 300 in Washington, DC.	• Over 25% did not enroll their children in the school they preferred owing to transportation difficulties. • Almost 67% said they would choose a better school farther away if better transport options were available.	Transportation is a barrier when choosing schools.

[a]Information from email correspondence between Peter Hurst (Boulder Valley Public Schools, Transportation Options Program Specialist) and Kevin J. Krizek, May 22, 2013.
[b]This number is underestimated because it is often the students who live close to school who walk or bike. Even rounded up to 3.0, the number is still too low.
Notes: The questions, purpose, and orientation of these studies and cases vary considerably. GIS = geographic information system; SOV = single occupancy vehicle; VMT = vehicle miles traveled; NMT = non-motorized travel.

points that help articulate different approaches to analyzing school choice and its impacts on transportation. The literature highlights the following points:

1. School choice is important and affects many children. Based on survey or school district data from Eugene, Oregon; Oakland, California; and Boulder, Colorado, the percentage of students who do not attend a neighborhood school are 37 percent, 49 percent, and 36 percent, respectively.
2. Transportation is an issue for school choice participants—and typically one that is worth overcoming for more-advantaged families.
3. School choice changes the mode of student travel. Attending a neighborhood school corresponds with shorter travel distances and more walking and biking. The reverse is also true, with more school choice students driving or being driven.

The literature and thinking have fallen short in using these observations to develop next steps for evaluation and analysis—namely, what can one surmise about the relationship between the extent of school choice and key transport costs (i.e., busing and environmental emissions)? For example, is there a monotonic relationship between school choice numbers and transport costs? And what are various cost implications (monetary and environmental) for expanding the scope of transport services to accommodate school choice? Additional robust tools, which are widely used in other parts of transportation analysis, are necessary to help school districts and communities explore the impacts of school policies on transportation. The existence of empirical research, however, makes development of the first generation of analytical tools and approaches possible, as presented below.

Case: Measuring and Modeling Costs in St. Paul

Understanding the elasticity of school travel mode to school choice is necessary to simultaneously evaluate choice and transportation policies. To drill down into these more specific applications, we investigated St. Paul Public Schools (SPPS) to better specify the transport costs associated with school choice.

St. Paul, Minnesota, is a city of 290,000 people and covers 56 square miles. The St. Paul public school district currently serves a diverse population of 39,000 students, a slight decrease from the 40,500 when the survey was conducted in 2007. At that time, over 91 percent of St. Paul elementary students lived within 1 mile of an elementary school, and 52 percent lived within 0.5 mile. Of St. Paul's 55 elementary schools, 21 were designated as neighborhood schools (mean enrollment of 392 students), and 34 were designated as magnet schools (mean enrollment of 324). In 1974, almost all students in St. Paul walked or biked to their neighborhood school. As a result of policies to increase neighborhood school diversity, St. Paul elementary students are now eligible to attend magnet schools, and in 2005, 67 percent of students attended a school that was not in their neighborhood. When the survey was completed, SPPS provided bus transportation to students living more than 1 mile from their school.[5] This policy has since been altered to provide service to students living more than 0.5 mile from their school. The contours of this school transportation policy are similar to policies in other districts. Elements of this study have been published elsewhere (Marshall et al. 2010; Wilson et al. 2010; Wilson, Wilson, and Krizek 2007). This section provides an overview of the research trajectory and summarizes the approach for measuring the elasticity between school choice and specific dimen-

5. Of the top 100 school districts in the United States, SPPS is ranked 39th in the number of students transported and 69th in the number of vehicles used for transportation, with St. Paul averaging 90 students per bus, compared to a national average of 57 students per bus (St. Paul Public Schools Transportation Department n.d.).

sions of transport costs: monetary (public and private) and environmental emissions. This work presents an important first step in building models and scenarios to estimate different transport outcomes.

The approach employed can be broken down into four steps:

1. Parental survey results were used to develop a statistical model of children's commute modes.
2. These data and the model were applied to a citywide sample. The survey-derived multinomial logit regression model of school commute travel mode (bus, automobile, walking) was used to estimate automobile and bus routing and emissions, and the corresponding policy scenarios were considered.
3. The impacts of different school choice policies on children's commutes were tested using routing software.
4. Cost estimates for vehicle use and the U.S. Environmental Protection Agency (EPA) model MOBILE6 were used to estimate emissions for both buses and private vehicles in order to evaluate the economic and environmental impacts of the policy shifts (U.S. Environmental Protection Agency 2006).

The purpose of each step, the approach used, and the primary findings are summarized in Figure 8.1.

STEP 1: CALCULATING TRIP LENGTH AND ASSIGNING TRAVEL MODE

The first step was to understand the basic dimensions of existing trip lengths and corresponding modes. In May 2007, 8,744 surveys were mailed to households with school-age children (grades K–6) in St. Paul (6,000) and Roseville (2,744), Minnesota.[6] The response rate was 21 percent. As all schools served grades K–6 but only a few served K–8, the analysis concentrated on children in grades K–6, resulting in 1,264 usable surveys.[7] Additional information about the survey,

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6. All households received an English survey; a Spanish, Hmong, or Somali version was added where SPPS records suggested a non-English primary home language. Reminder postcards for all surveys followed one week later.

7. The response rate was similar to that of other SPPS studies. Nonresponse bias in the outcome variable was investigated by comparing modal splits by distance traveled to school among survey respondents with national estimates. Similar rates of walking and motorized travel for trips of the same distance were found. When nonresponse by demographic characteristics were assessed, Caucasian and wealthier households were more likely to respond to the survey, but the sample included substantial responses from minority groups (9 percent African American, 11 percent Asian, 8 percent Latino) and lower-income families (25 percent from households with incomes less than $40,000).

Figure 8.1
Sequence of Steps to Estimate Transport Costs of School Choice

Using setting of St. Paul, Minnesota (and St. Paul Public Schools), as the case study.

1

Purpose	Survey to cover how far children travel to school, what type of school they attend, and by what mode they travel.
Approach	Survey response of 1,264 households.
Findings	Walking and driving are more common for neighborhood schools. Compared to neighborhood school students, choice school students walk two-thirds less, are driven one-quarter less, and depend on the bus twice as much (Wilson et al. 2010).

2a

Purpose	Generalize survey findings via model for student population of entire school district.
Approach	Apply survey data to estimate logit model of mode use.
Findings	Odds of busing are 2.6 times greater for magnet students than for neighborhood students.

2b

Purpose	Distance routing for different modes.
Approach	Employ shortest network GIS routing.
Findings	Trip distances vary significantly under different policy assumptions and estimates of total miles traveled.

3

Purpose	Estimate economic costs and emissions for different modes and distances for five pollutants: CO, CO_2, $PM10_{10}$, NOx, and VOCs.
Approach	Apply results from logit model to estimate distances and multiply by location-specific emissions factors calculated from MOBILE6 and from estimates of the cost of transportation via different modes (from the literature and operational costs of the school district).
Findings	Total economic costs and MOBILE6 emissions vary significantly depending on the scenario chosen.

4

Purpose	Estimate effects from five different scenarios.
Approach	Summarize and compare miles traveled, economic impacts, and emissions estimates from different policy scenarios.
Findings	In St. Paul, estimated travel distance can vary by a factor of 4 to 5 between school-choice and neighborhood-only scenarios; emissions can vary by a factor of 7 to 8 depending on the scenario.

including descriptive statistics of the results and an evaluation of the representativeness of respondents, is available in Wilson and colleagues (2010).[8] The analysis showed that children's commute modes and parental attitudes toward school selection differed by school type (magnet versus neighborhood), income, and race. Relative to neighborhood (i.e., nearest) schools, school-choice schools drew from larger geographic regions and had lower rates of walking, biking, and commuting by automobile and higher rates of busing.[9]

The St. Paul respondents were subsequently investigated using multinomial regression to identify the determinants of travel mode (automobile, school bus, or walking; N = 803 students). Travel distance had the single greatest effect on travel mode, though school choice, trip direction (to or from school), and grade played a role.

STEP 2A: APPLY MODEL RESULTS DISTRICTWIDE

Based on the initial survey results and model, the findings from the representative sample were applied to characteristics of students in the school district as a whole. A logit model was constructed to predict a student's dominant school travel mode among automobile, bus, and walking (the odds of busing or walking relative to the reference mode, automobile).[10] This model formed an important and underlying basis for the subsequent analysis and assumptions.

The model was applied to all SPPS elementary-age children to estimate travel modes;[11] the fact that the model uses only those variables available for all SPPS students was taken into account, thereby allowing direct application of it to the

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8. The 22 survey questions included home and school locations, grade, race, gender, and to- and from-school commute mode. Respondents indicated the number of days the previous week their child with the most recent birthday traveled to and from school via private vehicle, school bus, walking, biking, or another mode.

9. Parent attitudes toward transportation also differed by race and school type. For example, parents of nonwhite and school-choice students placed greater-than-average importance on bus service and quality.

10. Estimating the dominant travel mode introduces some inaccuracies, but such an approximation (i.e., evaluating dominant travel mode only) appeared to be appropriate: children used one mode of travel for 77 percent of to-school trips, 80 percent of from-school trips, and 60 percent of all weekly trips. A minority of students (16 percent) switched dominant mode between to- and from-school trips.

11. Data on all 19,655 elementary-age students in SPPS were acquired in March 2008 through a research agreement with the school district. The 1,046 students (5 percent) enrolled in SPPS yet living outside district boundaries were excluded, yielding 18,609 children. The reasons for removing those 5 percent of students (likely children who had previously lived in St. Paul and remained as SPPS students after moving nearby) included the facts that busing was available only to students residing within the SPPS boundaries and that the dominant travel mode for this 5 percent was automobile (84 percent). The policies evaluated here would not have directly altered the mode choice of those families.

districtwide sample.[12] Each child was randomly assigned a commute mode based on the probabilities estimated by the model. Model uncertainty was estimated by comparing predictions against the 803 survey responses.[13]

The model has a pseudo-R^2 of 0.54 and correctly predicted the travel mode for 75 percent of the students (see table A8.1).[14] The model exhibited reasonably good agreement with input data, especially considering the few explanatory variables included in it and the stochastic nature of predicting travel modes (i.e., randomly selecting a mode based on the logit-calculated probabilities).

For the 803 survey respondents, the proportions of students busing, traveling by automobile, and walking were 74 percent, 13 percent, and 13 percent, respectively, in the model predictions, and 63 percent, 25 percent, and 13 percent, respectively, in the survey data.[15] Some of the trends in table A8.1 are nonmonotonic. In some cases, those trends involve statistical P values that indicate the coefficients are not statistically significant (e.g., busing odds ratios for grades 2, 3, and 4). In other cases, the trends are statistically significant but still suggest a consistent 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 one order of magnitude more likely than the reference mode).[16] The robustness of other dimensions of the model also was tested.[17]

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12. More information about the detailed logit model is available in Wilson et al. (2010).

13. The robustness of the findings to perturbations in input data was explored by generating separate models for six subsets of the data (three random subsets and three pseudo-random subsets).

14. For example, for walking, at a commute distance of 0.8–1.2 km, the regression coefficient is −1.828, 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 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 auto) at 0.8–1.2 km are 16.1 percent 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 likelihood of walking, busing, and being driven are 70 percent, 7 percent, and 23 percent, respectively.

15. Predictions were more accurate for busing and walking (78 percent and 71 percent, respectively) than for traveling by automobile (58 percent).

16. These nonmonotonic trends emphasize the importance of using categorical variables (see table 8.1) rather than linear regression.

17. To explore the robustness of the model to perturbations in input data, subsets of the input data were used to generate analogous models as table 8.1. Three subsets were random (in each case employing two-thirds of the data [N = 535]), and three subsets were pseudo-random (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 for these six models are similar to those for the main model. Correct predic-

As expected, the odds of walking decline rapidly with longer travel distances. For distances more than 1.6 km (1 mile), the odds of walking are nearly zero (less than 2 percent of the odds of being driven). The reverse holds true for busing. The odds that a student will bus are six to ten times greater for distances more than 1.6 km than for the reference distance, likely mirroring the SPPS busing policy of providing bus service at distances greater than 1.6 km (1 mile). The odds of busing are not statistically different at distances less than 1.2 km than at the reference distance.[18]

The odds of busing are 2.6 times greater for school-choice students than for neighborhood-school 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 schools than for neighborhood schools.) Busing and walking are generally more likely among older children than kindergartners: the busing odds relative to kindergartners range from 1.6 to 4.4, and the walking odds for fifth and sixth graders relative to their kindergarten classmates are 2.6 and 8.6, respectively. Finally, the odds of busing are three times lower for whites than for nonwhites. Neither race nor gender is a significant predictor of walking odds.

STEP 2B: DETERMINING VEHICLE ROUTING

Next, travel distances of alternate bus routes were estimated for purposes of calculating total system miles and estimating transport costs and environmental emissions. The shortest network-distance travel routes for automobile or walking were estimated using ArcGIS, given origins and destinations of school and home. In addition, bus routes for each school were estimated using a series of constraints and optimization procedures.[19] Key findings suggest that basic systems assumptions can have large impacts on modeled results. The aim was to replicate

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tion rates and pseudo-R^2 values for the six models (71–77 percent and 0.52–0.61, respectively) are consistent with those for the main model (75 percent and 0.54, respectively). These findings suggest that the logit model is reasonably robust to perturbations in input data.

18. Interestingly, the odds of walking to school are 61 percent of the odds of walking from school, a finding consistent with previous research (Vovsha and Petersen 2005; Schlossberg et al. 2006). Busing appears to follow a similar trend (lower odds to school than from school), but at a 90 percent confidence interval, the difference is not statistically significant.

19. ArcLogistics optimization was used with the following constraints: (1) no bus stop exceeds one-third mile from a student's home; (2) buses begin their route at a central location (i.e., the First Student bus depot on Como Avenue, St. Paul); (3) buses arrive at the school at least 10 minutes before the school's start time; (4) loading time is 30 seconds per stop; (5) maximum trip length is one hour; (6) maximum seating capacity is 77 students; and (7) buses may drop off students at the school only once, at the end of the route. These constraints reflect SPPS bus practices at the time of the study. The two options for optimizing bus routes and number of

actual SPPS school pickup policies and behaviors, while recognizing that actual routing (which is done by hand) might vary significantly.

STEP 3: ESTIMATE ENVIRONMENTAL EMISSIONS

To estimate emissions, rates from private vehicles and buses were calculated, and the EPA's MOBILE6 model was used to estimate emissions rates per mile traveled for five pollutants: carbon monoxide (CO), carbon dioxide (CO_2), particulate matter 10 micrometers in diameter (PM10), nitrogen oxides (NOx), and volatile organic compounds (VOCs). MOBILE6 emissions rate estimates are tailored to local climate conditions and separately provide running emissions during vehicle operation and non-running emissions such as cold-start, hot-soak, and diurnal breathing losses; however, they do not include specifics on local topography. The survey respondents indicated whether school commutes were sole-purpose or multipurpose trips. For sole-purpose trips, miles traveled and emissions were estimated as one round-trip between home and school, and for multipurpose trips (i.e., trip chaining), miles traveled and emissions were estimated to be one-half of a one-way trip between home and school.

The study also explored whether fleetwide average emissions factors from MOBILE6 were appropriate surrogates for vehicles employed by families with elementary-age children. To do this, vehicle age and fuel economy for the vehicles driven by a random sample of 165 survey respondents were examined (U.S. Department of Energy 2007).[20]

STEP 4: ANALYZE SCENARIOS

Relying on the study model, different scenarios were put forth to explain projected differences in various school choice and transportation policies, based on the initial modeled data. This step represents an effort to better understand the elasticity between different school choice policies (e.g., not allowing versus allowing within-district choice; decreasing busing) and to evaluate their specific implications. The characteristics and assumptions of the scenarios, as well as the projected results, are described in this section.[21]

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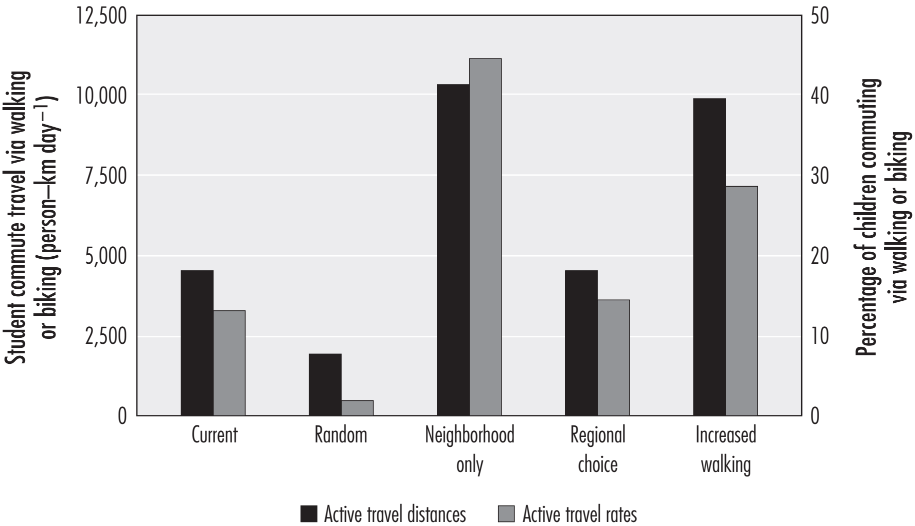
buses are time and distance; both options yield identical or very similar results for the situations investigated here.

20. Fuel economy was calculated based on vehicle make, model, and year (U.S. Department of Energy 2007). The resulting fuel economy values (mean, 20.55 miles per gallon [mpg]; standard deviation, 4.21 mpg) are comparable to the MOBILE6 fleetwide average (20.4 mpg). That is also true for vehicle age (median [mean] age, 8 [8.1] years for survey respondents and 8 [8.3] years for the MOBILE6 database), suggesting that MOBILE6 provides reasonable estimates for the questions considered here.

21. These steps were followed for each policy scenario: (1) started with the base case (current situation); (2) modified the schools attended according to the scenario; (3) relied on the logit model to determine travel mode for each child (for the SRTS scenario, reassigned some students to walking); (4) used ArcLogistics to determine school bus routes; and (5) calculated

Figure 8.2
Student Commuting via Active Travel by Scenario



Source: Marshall et al. (2010).

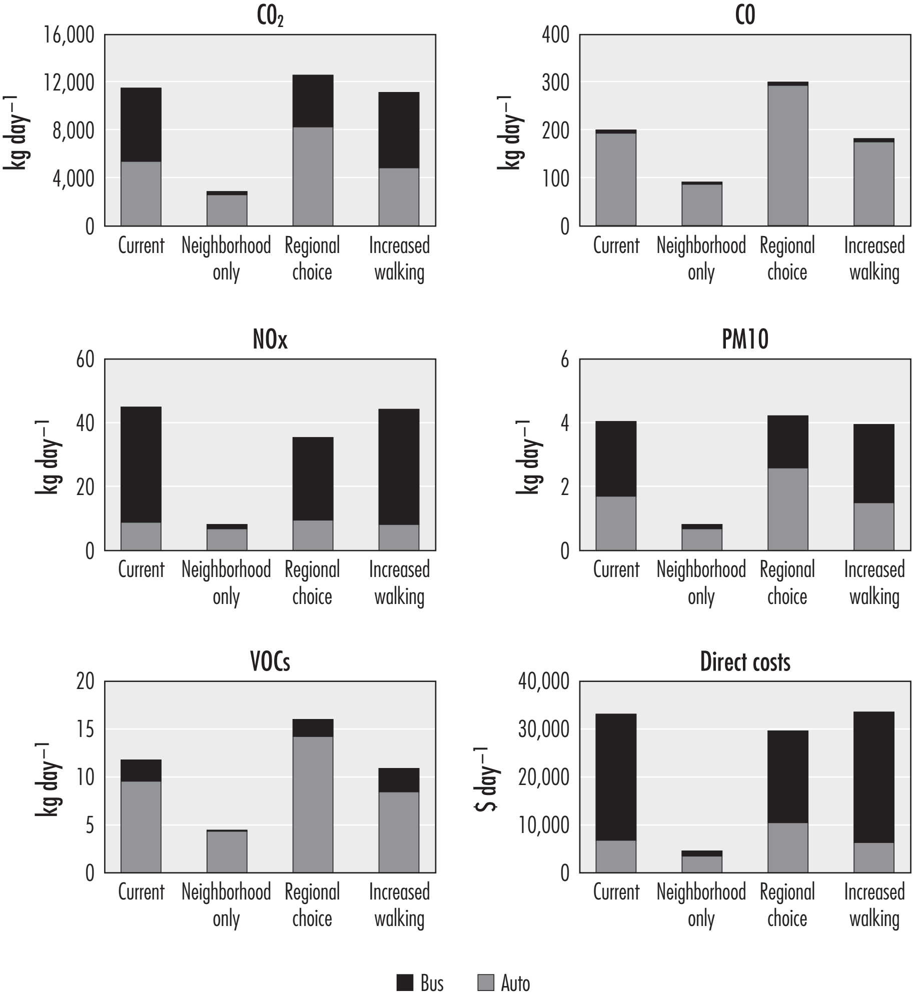
Table A8.2 presents estimated travel demand by mode for each scenario. Rates and distances of active travel per scenario are shown in figure 8.2. Emissions estimates are summarized in figure 8.3. Results per scenario reflect shifts in travel distances and modes, and differences in emissions for automobiles versus buses.

Current This is a reflection of the base case, where students are modeled as attending the school they actually attend. Among surveyed children, 65 percent attended a magnet school and 35 percent attended a neighborhood school. Among all SPPS students, the divide is similar: 68 percent magnet and 32 percent neighborhood. Only 24 percent of surveyed children (20 percent of SPPS students) attended the school that was closest to their home.

The median travel distance is 3.4 km. Relative to magnet school students, neighborhood-school students have about a two times shorter average travel

vehicle emissions and costs. Costs per vehicle-km were $4.46 for SPPS buses (Minnesota Department of Transportation 2009) and $0.34 for private vehicles (American Automobile Association 2009).

Figure 8.3
Emissions and Direct Costs of School Travel by Scenario



Note: Emissions were estimated with existing technologies; retrofits or other emissions reduction technologies (e.g., electric vehicles or diesel retrofitting) were not considered. No change in the location of homes or workplaces was assumed.
Source: Marshall et al. (2010).

distance, two times lower busing rates, two times higher automobile rates, and three times higher walking rates. The percentage of students living within 1 mile of school is about two times greater for neighborhood schools as for magnet schools (46 percent versus 19 percent).

Random This scenario represents the other extreme of school choice: a situation in which location or travel distance does not matter.

Relative to the base case, average commute distance nearly doubles (from 4.0 km to 7.1 km). Walking rates decrease dramatically (from 13 percent to 2 percent), and the total distance walked decreases 59 percent. Use of automobiles decreases (in terms of rates of use), but because of the longer commute distance, total travel distance by automobile nearly doubles. Busing rates increase, and busing passenger distance nearly doubles. This scenario represents a bounding exercise only; emissions and costs for this case were not estimated.

Neighborhood Only In this scenario, attending non-neighborhood schools is not permitted; all students are assigned the school closest to their residence. Therefore, the scenario represents the minimum necessary commute for connecting students and schools.

The neighborhood-only scenario (i.e., eliminating school choice) reduces average travel distance four- to fivefold. Walking rates increase three- to fourfold, and distance walked more than doubles. Automobile rates increase, but owing to shorter commutes, distance traveled by auto is more than cut in half. Busing rates drop by more than half, and busing distance declines by more than an order of magnitude. Emissions are three to eight times lower for the neighborhood-only scenario as for current conditions.

Regional Choice This scenario divides the district into three equal-size zones; parents choosing a non-neighborhood school must select from among schools in their own zone. These zones were selected based on conversations with SPPS staff to mimic most likely zones if this policy were enacted. Currently, 67 percent of students attend a school inside their zone, and the rest (33 percent) 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.[22]

In this case, the 31 percent of students attending a school outside their own region were modeled as switching schools. Median and mean travel distance are

22. At the suggestion of SPPS staff, five districtwide schools were maintained 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 schools.

unchanged, and walking rate and walking distance are nearly unchanged. Distance bused decreases about 7 percent, but automobile usage increases, with distance traveled by auto increasing about 50 percent. The net emissions impact is a 13 percent reduction for NOx and a 4–45 percent increase for the remaining pollutants. The fraction of emissions derived from buses decreases. The bus load factor, which is a measure of the efficiency with which busing service can be offered, increases about 30 percent (average passenger-km per vehicle-km is 21 for current and 27 for regional choice).

Increased Walking This scenario reflects an extreme case of SRTS. It mirrors the current scenario (i.e., school each student currently attends not modified) but assumes that all children within a certain radius of their school must commute via walking. The radius selected is 1 mile (1.6 km), with 0.5 mile (0.8 km) as a sensitivity analysis.[23]

Here, the approximately 27 percent of students living within 1 mile of their school convert to walking. Walking rates and walking distance more than double. Automobile usage declines 8 percent (from 19 percent to 11 percent), and auto travel distance declines about 13 percent. Busing rates decrease 7 percent, but total distance bused decreases only about 2 percent, because few children living within 1 mile of their school are currently bused, and because shifting those students' travel mode does not significantly alter the bus routes. Emissions decreases are 1–12 percent.

Table 8.3 provides estimates of direct costs for transportation for each scenario. The regional-choice scenario reduces bus costs but increases costs for private automobiles; analogous results hold for emissions. Travel costs are more than seven times greater for current school-choice students as for neighborhood-only students. As discussed in the next section, cost estimates are sensitive to the use of local versus national data.

Discussion Specific to the SPPS Modeling Case Application

The results of the modeling efforts from SPPS highlight the effects of school choice on the 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 four to seven times greater for regional school choice and three to eight times greater for current school choice. Transportation costs and rates of active commute travel (walking/biking) are

23. These two distances reflect both district policy that bus service is guaranteed only for students commuting more than 1 mile and our observation based on the current data, and are consistent with the available literature, that walking rates are much greater for commute distances less than 0.5 mile than for distances greater than 0.5 mile.

Table 8.3
Transportation Costs by Scenario, Using Local Versus National Data

Scenario	Using Local Costs	Using National Costs
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%)

Note: Dollar amounts indicate combined (bus + automobile) direct costs per day. Values in parentheses indicate percentage attributable to bus costs.
Source: Marshall et al. (2010).

eight times greater and three times lower, respectively, for the current scenario as for the local-only scenario (Marshall et al. 2010).

The emissions impacts of the increased-walking (SRTS) and regional-choice scenarios are surprisingly modest—a finding that may or may not hold in locations without school choice. Because many students attend a school farther away than they wish to comfortably walk (i.e., commute distance greater than 1 mile), efforts to improve walking safety (SRTS) have minor impacts on the overall system in terms of emissions (although the SRTS scenario does project increases in walking rates relative to the current scenario, as noted in figure 8.1). In the regional-choice scenario, the 33 percent of students who would change schools would receive a random new school in their choice region; the new school would not necessarily be closer than their previous school. This assumption could be further tested with additional analysis and behavioral data. 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 yield reduced costs and emissions, especially when public (bus) and private (automobile) costs and emissions are analyzed in tandem.

Eliminating districtwide school choice (i.e., returning to a system with neighborhood schools only) would have significant impacts with respect to transport modes and reducing emissions. Proposed shifts in school choice and bus provision policies (e.g., proposed zone-based school choice) would have only modest impacts. Furthermore, policies that would curtail bus use may reduce bus emissions but yield larger system-total emissions due to increases in private vehicle emissions. Two of the policy scenarios tested in this study yielded only modest impacts on school commuting and emissions (regional choice and increased walking); the third scenario yielded significant shifts in travel and emissions (neighborhood only). The one finding that is most stable is that policies such as school choice and school siting conflict with the goal of increasing rates of non-motorized school commuting.

Given that local rather than national data were used to estimate financial costs, it is helpful to consider the degree to which the previous estimates are transferable to other metropolitan areas. For example, bus costs are higher in St. Paul (\$4.46 km^{-1}) than the national average (\$1.76 km^{-1}), which influences the outcomes (American Automobile Association 2009). Among the four scenarios considered in figure 8.3, the third-most-expensive option (regional choice) becomes the most expensive option if one employs national rather than local bus-cost data (table 8.3). 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.

Further Discussion and Reflections

The purpose of this chapter is threefold: (1) to present the latest thinking on the transport and environmental costs of school choice; (2) to offer approaches for integrated evaluation; and (3) to articulate, in detail, one research application to understand different scenarios. In so doing, the work addresses key dimensions of this issue: contextual, methodological, and policy.

Four key insights emerge from this research to help inform future directions for this type of work and its implications for policy discussions.

First, the costs of transport come in many forms (table 8.1). The approach here focused primarily on two of them, emissions and public and private transport expenses. Secondarily, this study draws attention to walking and biking as efforts to support physical activity. We are not aware of efforts to measure some of the other dimensions, but this is not to suggest they are less important. Some costs are certainly harder to measure (e.g., costs of convenience), and others might have direct policy relevance (e.g., costs of busing). Also, it might be helpful to articulate transport costs to the school district versus emissions costs to society.

Second, within the scholarly literature, McDonald (2007) is largely credited with bringing attention to the incongruence between national programs such as SRTS and the fact that large portions of children do not attend their neighborhood school.[24] As the current study shows, school choice can dramatically reduce active travel and unintentionally undermine the impacts of SRTS interventions. With widespread interest and investment in SRTS and school choice, additional focus on the intersection of these topics is warranted. Such research could help

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24. If policy makers want to increase walking rates, current policies such as SRTS that do not affect the spatial distribution of schools and residences will not be enough to change travel behavior.

discern the degree to which these two goals can be harmonized or determine whether they are always contradictory.

Third, school district policies are driven by the quest for educational quality and balanced by other salient issues, including budgets, larger social goals such as equity and diversity, and federal and state standards. Other factors, such as school transportation and its impacts, tend to fall by the wayside. Until recently, environmental considerations have not been widely considered in school district policies. This topic, and the results of the current study, show that inadvertent choices can have significant environmental consequences and that shifts in activity level (vehicle-km traveled) have a strong influence on CO_2 and other vehicle emissions. These calculations spill over into other areas, such as school closures (Müller, Tscharaktschiew, and Haase 2008) and have implications for siting (McDonald 2010). For example, an increasingly important issue that school districts wrestle with involves choosing between investing resources in an existing school (upkeep and maintenance) and building a new school near current population centers or in greenfields farther (more than 1 mile) from residential areas. The current study highlights the merits of locating schools relatively closer to students' homes from the standpoint of travel costs and provides quantitative estimates for doing so. These estimates can now be integrated into discussions and decisions vis-à-vis proposed benefits of greenfield schools, such as the amount of space, the adequate provision of facilities, and other "newness" factors.

Fourth, there are several competing societal objectives embedded within these discussions. When addressing one part of the issue, researchers need to fully consider its relationship to others, as key elements are codependent. Furthermore, any research on these issues incorporates, either directly or indirectly, several assumptions unique to particular school district policies (e.g., at what distance to permit busing), household and student preferences (e.g., will students walk given short distances), a family's commute patterns (some parents can conveniently drop their children off en route to work), or fleet characteristics (of school buses or private vehicles). Some of these dimensions are easier to measure or forecast than others, but all are linked within complex systems. For example, it is important to consider underlying factors such as the pull toward school choice. This relates directly to the distance at which busing is guaranteed, which in turn relates to parents' willingness to transport children in the absence of busing or walking. Furthermore, it may be that higher-income families or dual-income families are more able to drive their children to school en route to work. In such a case, there may be little cost burden imposed on parents. Measuring emissions costs is another complicated task. Emissions estimates are sensitive to the age of the school bus fleet and the route distance. Analyses must be tailored to particular circumstances to yield meaningful results in this regard. In many respects, cracking the nut of the school choice–transport cost relationship is analogous to solving a dynamic optimization problem that engages several degrees of freedom.

As researchers and policy analysts design future school choice and transportation policies, they must acknowledge and consider the complexity of the system and the effects their decisions will have across the system. School choice has a rich history in the education literature, but researchers in this field have not paid much attention to the direct or indirect costs of transportation. The rapidly developing SRTS literature has just recently begun to focus on the fact that half of the students in many school districts do not attend their neighborhood school and are unable to walk or bike to school.

Fortunately, recent research is increasingly incorporating the systematic view of the problem by weaving together analysis of environmental costs, busing costs, and fleet characteristics. The larger picture, however, suggests that the context is more complicated than this first-generation model and that estimating the elasticity of transport costs to school choice is fraught with difficulty. Additional analysis to incorporate other dimensions is welcome and necessary to advance the field.

Conclusions

The research presented here allows for a more detailed examination of the interplay between school travel and school choice, and the economic and environmental impacts of these policies. Overall, the findings underscore the need to simultaneously and critically analyze and evaluate transportation-related economic, environmental, and health impacts of proposed changes in school policies.

Children's travel is unique. It is often shaped by the decisions of parents, schools, and school districts. As governments and school districts continue to support school choice, incorporating and evaluating transportation-related impacts and their consequences as larger societal goals become more crucial. Often, a comprehensive analysis of school transportation falls through the cracks; educational policy researchers focus on academic outcomes, and transportation and environmental researchers do not consider the system large enough to warrant extensive study. This chapter highlights the importance of the topic and presents methods and tools to aid researchers and policy makers in future analyses. Such analyses will help inform education policies and ensure that scarce resources are well spent. Well-designed school transportation systems can potentially provide health benefits and improve safety, while also reducing transportation costs, environmental impacts, traffic congestion, and parents' school-related travel.

Table A8.1
Multinomial Logistic Regression Model

Variable	Bus[a]				Walk[a]			
	Coef.	Std. Error	P > |z|	Odds[b]	Coef.	Std. Error	P > |z|	Odds[b]
	–1.269	0.558	0.023		1.101	0.467	0.018	
Trip type, to school (0 = from school)	–0.195	0.133	0.145	0.823	–0.497	0.224	0.027	0.609
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
School type, magnet (0 = neighborhood)	0.939	0.145	0	2.56	–0.022	0.230	0.924	0.978
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
Race, white (0 = nonwhite)	–1.15	0.170	0	0.318	0.052	0.287	0.857	1.053

[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 $P < 0.001$.
[b]Odds ratio is the probability that an event will occur divided by the probability that an event will not occur.
Source: Marshall et al. (2010).

Table A8.2
Estimated Daily Travel by Scenario

Scenario	Current			Random	Neighborhood Only	Regional Choice	Increased Walking
	Magnet	Neighborhood	Total				
Number of students	12,694	5,915	18,609		18,609		
Travel distance (km)							
Mean	4.6	2.6	4.0	7.1	0.8	4.0	4.0
Median	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)	7,003	4,133	11,136	20,251	5,064	16,362	9,725
Walk (km)	1,029	1,027	2,056	832	4,691	2,030	4,902
Bus (vehicle-km)	2,448	499	2,947	5,370	146	2,090	3,005
Bus (passenger-km)	50,278	10,263	60,541	109,754	3,934	55,773	59,107
Total district passenger travel from school[a]							
Auto (km)	5,863	3,518	9,381	17,309	3,981	14,027	8,224
Walk (km)	1,240	1,211	2,451	1,138	5,613	2,546	5,032
Bus (vehicle-km)	2,494	519	3,013	5,498	144	2,157	3,074
Bus (passenger-km)	51,237	10,664	61,901	112,970	5,696	57,590	60,477

[a]Sum of student travel distance by mode. For auto, vehicle-km is equal to passenger-km.
Source: Marshall et al. (2010).

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