The "Path" Not Taken: Exploring Structural Differences in Mapped- Versus Shortest-Network-Path School Travel Routes

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Objectives. School route measurement often involves estimating the shortest network path. We challenged the relatively uncritical adoption of this method in school travel research and tested the route discordance hypothesis that several types of difference exist between shortest network paths and reported school routes.

Methods. We constructed the mapped and shortest path through network routes for a sample of 759 children aged 9 to 13 years in grades 5 and 6 (boys = 45%, girls = 54%, unreported gender = 1%), in Toronto, Ontario, Canada. We used Wilcoxon signed-rank tests to compare reported with shortest-path route measures including distance, route directness, intersection crossings, and route overlap. Measurement difference was explored by mode and location.

Results. We found statistical evidence of route discordance for walkers and children who were driven and detected it more often for inner suburban cases. Evidence of route discordance varied by mode and school location.

Conclusions. We found statistically significant differences for route structure and built environment variables measured along reported and geographic information systems–based shortest-path school routes. Uncertainty produced by the shortest-path approach challenges its conceptual and empirical validity in school travel research. (*Am J Public Health.* 2013;103:1589–1596. doi:10.2105/AJPH.2012.301172)

Recent policy and research on children's school travel has responded to reports of decadal declines in active school travel (AST)—that is, traveling to or from school under one's own power, typically on foot or using a bicycle—in many Western nations.[1–6] Evidence of a similar trend is also beginning to emerge in some cities in the global south.[7] AST decline has been matched by increased prevalence of overweight and obesity in children and youths.[8–10] Children driven to and from school and other activities miss transport-centered opportunities for physical activity and health benefits[11–13] that, when combined with physical activity from other sources, could produce an active healthy lifestyle that may be sustained into adulthood.[14–19] Understanding how to encourage AST could progress through development of valid evidence about the relationship between school travel route characteristics and travel mode choice.

School travel research has often examined the relationship between travel mode choice and home, school, and route environments.[20] Underpinning this work is the hypothesis that built environment (BE) features may enable or restrict household transport choices. A mix of BE effects, with some indication of difference by age, time of day, location (e.g., home, route, or school), and measurement approach (e.g., objective or subjective assessment), have been found.[21–23] Studies of home, school, and travel mode without route information have suggested that both objective measures and perceptions of BE features and their use (i.e., traffic on busy roads) predict AST.[21,23–25] Reported effects are not always in the same direction across studies. The odds of walking have been shown to increase with residential density in some studies but not in others.[21,23,24] Marked differences in BE effects have also been reported when separate models are estimated for the morning and afternoon school travel periods.[21] For example, and unique to their school-to-home model, Larsen et al.[21] found that the effect of mixed land use (AST is more likely with mixed land use) intensified for the trip home; residential density became significant, along with income (i.e., AST is more likely in lower income neighborhoods); and a street tree effect (i.e., trees provide shade and are a direct and indirect measure of neighborhood aesthetics), significant in the morning model, was not reproduced.

Route-based studies extend the home, school, and travel mode work by including BE features that children might experience along their route that could influence a household's school travel decisions. For example, a child's possible interaction with busy roads while walking to or from school could underlie a parent's decision to drive. Route-based studies have typically involved measuring BE characteristics along and around assumed routes modeled using a geographic information systems (GIS)–based shortest-network-path algorithm.[26–32] Although several diverse route effects have been reported, all studies have reproduced the finding that children are less likely to walk as route distance increases.[26–32] Here again, different effects are reported for to- and from-school trips.[26,27] For example, Larsen et al.[26] reported significant effects for the presence of street trees, detached housing, and land use mix, that did not materialize in their school-to-home model. Findings regarding route directness, typically measured as the deviation of an assumed GIS-estimated route from the straight-line distance between home and school, have also been inconsistent. For adults, route directness is often associated with the use of active modes. In the school travel literature, the opposite effect,[28,30] or no effect,[26,27] has been found. Several studies have

TABLE 1—Univariate Description, Walking as Primary Mode to and From School: Built Environment and Active Transportation Project; Toronto, Ontario, Canada; Spring and Fall 2011

Variable	Mean (Median; SD)	No.
Route distance, m		
Home to school, mapped	565.80 (506.10; 342.36)	561
Home to school, shortest path	605.90 (542.50; 348.40)	561
School to home, mapped	584.60 (515.00; 371.22)	561
School to home, shortest path	605.90 (542.50; 348.40)	561
Proportion of segment overlap		
To school	0.53 (0.59; 0.37)	561
From school	0.50 (0.56; 0.37)	561
No. of major intersections crossed		
To school, mapped	1.31 (0.00; 2.57)	561
To school, shortest path	1.57 (1.00; 2.51)	561
From school, mapped	1.37 (0.00; 2.71)	561
From school, shortest path	1.57 (1.00; 2.51)	561
Route directness		
To school, mapped	0.72 (0.72; 0.14)	501
To school, shortest path	0.71 (0.74; 0.18)	501
From school, mapped	0.71 (0.72; 0.15)	503
From school, shortest path	0.71 (0.73; 0.20)	503
Central city		
Route distance, m		
Home to school, mapped	573.60 (524.60; 337.99)	359
Home to school, shortest path	568.70 (525.50; 306.99)	359
School to home, mapped	592.20 (524.60; 376.51)	359
School to home, shortest path	568.70 (525.50; 306.99)	359
Proportion of segment overlap		
To school	0.55 (0.62; 0.35)	359
From school	0.54 (0.61; 0.36)	359
No. of major intersections crossed		
To school, mapped	1.71 (1.00; 2.98)	359
To school, shortest path	1.73 (1.00; 2.82)	359
From school, mapped	1.79 (0.00; 3.15)	359
From school, shortest path	1.73 (1.00; 2.82)	359
Route directness		
To school, mapped	0.72 (0.72; 0.13)	322
To school, shortest path	0.74 (0.75; 0.15)	322
From school, mapped	0.71 (0.71; 0.14)	320
From school, shortest path	0.74 (0.75; 0.15)	320
Inner suburbs		
Route distance, m		
Home to school, mapped	551.80 (468.90; 350.39)	202
Home to school, shortest path	671.90 (596.70; 404.31)	202
School to home, mapped	571.30 (478.60; 362.17)	202
School to home, shortest path	671.90 (596.70; 404.31)	202

Continued

reported some relationship between major roads (crossed or along a route) and AST.[26,28,30] Again, though, road-type effects may emerge for the school-to-home trip only[26] or not at all.[27] Child and parent self-report data have also indicated that a major road crossing may act as an AST barrier.[31] Lastly, although land use mix appears to be associated with AST, in both route- and non–route-based studies[25,26] scholars have appeared less certain about how land use in general (e.g., residential density, mix, street-facing windows) relates to or produces children's transport. The literature presently projects the view that certain types of land use place some combination of more "eyes on the street" and more people (children and adults) in the street, thereby affecting adult risk perceptions regarding social fears and traffic.[22,25] With the attenuation of adult risk perception, children may be more likely to engage in AST.[22,25]

Notably, BE features that associate with school travel-mode choice seem to vary within and across studies set in different locations. Perhaps one of the problems is that, for route-based work in particular, the assumed GIS-based route is not an accurate approximation of the actual route traveled. The statistical validity of shortest-network-path route estimation is questionable; the method may not produce an accurate approximation of actual student travel routes. In this article, we challenge the relatively uncritical use of the GIS-based shortest-network-path approach often used to produce school travel routes (to and from) and route environments when observed or reported route data are absent. The research is organized around 1 question: Do quantifiable differences exist between mapped (reported) routes to and from school and school routes estimated using a GIS-based shortest-path algorithm? We addressed this question by testing the route discordance hypothesis that several types of difference exist between shortest-path route estimates and school routes mapped by child respondents.

METHODS

The Built Environment and Active Transportation Project used mixed methods to study the relationship between the BE and elementary school travel in Toronto, Ontario, Canada.

TABLE 1—*Continued*

Proportion of segment overlap		
To school	0.49 (0.50; 0.39)	202
From school	0.45 (0.36; 0.39)	202
No. of major intersections crossed		
To school, mapped	0.60 (0.00; 1.35)	202
To school, shortest path	1.28 (0.00; 1.80)	202
From school, mapped	0.62 (0.00; 1.38)	202
From school, shortest path	1.28 (0.00; 1.80)	202
Route directness		
To school, mapped	0.72 (0.73; 0.15)	179
To school, shortest path	0.66 (0.69; 0.21)	179
From school, mapped	0.71 (0.72; 0.17)	183
From school, shortest path	0.66 (0.69; 0.25)	183

In January 2010, principals at all 469 elementary schools (with grades 5 and 6) within the Toronto District School Board received an invitation letter. In the pool of responding schools, 16 were sampled to ensure representation of a mix of income (low and high) and BEs (old and new central city and inner suburban neighborhoods). We obtained consent from school principals, parents and caregivers, and students. Participation was voluntary; retail gift cards were used as an incentive for households. Data collection took place in spring and fall 2010, with follow-up in spring 2011. A total of 881 parents or guardians consented and were asked to complete an activity-travel survey and mapping exercise.

Mapping Exercise

Children and adults (usually a parent) were recruited through selected elementary schools. Eligible grade 5 and grade 6 students were sent home with a consent form. We used address information from the consent form to create an aerial photomap of each respondent's neighborhood. We conducted GIS data entry, processing, and analyses using ArcGIS version 9.3 (Environmental Systems Research Institute, Inc., Redlands, CA). The most recent (2005) orthoimages (20-cm resolution) of the City of Toronto were obtained from the Map and Data Library at the University of Toronto. We imported these images into ArcMap (version 9.3; Environmental Systems Research Institute, Inc.) and used them to produce aerial photomaps of respondent neighborhoods. Home and school locations and street centerlines and names were added to each map. Each child was sent home with a custom map (on ledger-size paper) and red and blue markers to draw separate to- and from-school routes. Participants were asked to draw their usual route to and from school. Although children in the grades examined (ages 9–13 years) are capable of sophisticated verbal description and map-based interpretations of their spatial environments,[33] adult and child respondents were instructed to complete the mapping exercise together.

Geographic Information Systems and Shortest Path Estimation

We auto-geocoded student home addresses and manually adjusted them to respondent home locations. Orthoimagery from the mapping exercise was used to on-screen digitize school locations (n = 16) and respondents' reported to- and from-school routes. We manually adjusted school locations to the main door of the school building associated with the school address. A mode-conditioned (walked or driven) shortest path between each child's home and her or his school was estimated for each to- and from-school route using ArcGIS Network Analyst, version 9.3. We used travel time per road segment, based on the posted speed limit, as impedance for children who were driven; we used distance for walkers. Depending on travel mode, 2 different network data sets were used. Turn and directional (1-way streets) restrictions were applied in route estimation for children who were driven, but not for walkers. Walkers have greater spatial flexibility than drivers. We used City of Toronto network data, containing trails, laneways, and walkways, to enable the shortest path algorithm to search across regular streets and other linear features that walkers might use.

Discordance Measures

Primary measures of route structure included route distance and proportion of route segments shared between mapped and shortest paths. Secondary measures, estimated as a function of route structure, included route directness and number of major or minor arterial roads crossed. The proportion of shared segments was developed as an overlap index, O, for a person n taking a trip of type j:

$$(1)\quad O_n(j) = \frac{2e_{nj}}{(r_{nj} + s_{nj})},$$

where e is the distance of nonrepeating segments along the linear intersection between mapped- and shortest-path routes for a school trip j. The quantities r and s represent the length of mapped- and shortest-path routes, respectively, and index values ($0 \leq O \leq 1$) closer to 1 indicate greater overlap between reported and modeled routes. The index quantifies the extent to which a reported to- or from-school route overlaps with its corresponding shortest network path.

Route directness is often associated with active travel[34] and is expressed as

$$(2)\quad RDI = \frac{E}{R},$$

where E is the Euclidean distance between home and school and R is the route distance (reported or modeled). The Euclidean distance is the most direct vector between 2 locations. The RDI quantifies route deviation from a Euclidean benchmark. An index value ($0 \leq RDI \leq 1$) closer to 1 indicates a more direct route.

Adult concern about traffic may motivate the decision to drive a child to or from school.[25,35–37] Major street crossings, a frequently identified pedestrian safety issue, may influence route choice.[26] We used GIS to count the number of major and minor arterial roads crossed, from any other street type, along reported and shortest-path routes for to- and from-school trips. The City of Toronto's road classification system informed our identification of major or minor arterial intersections.

TABLE 2—Univariate Description, Being Driven as Primary Mode to and from School: Built Environment and Active Transportation Project; Toronto, Ontario, Canada; Spring and Fall 2011

Variable	Mean (Median; SD)	No.
Route distance, m		
Home to school, mapped	1529.00 (1248.00; 904.11)	99
Home to school, shortest path	1482.00 (1196.00; 915.24)	99
School to home, mapped	1623.00 (1375.00; 967.99)	99
School to home, shortest path	1543.00 (1361.00; 926.15)	99
Proportion of segment overlap		
To school	0.69 (0.85; 0.33)	99
From school	0.60 (0.67; 0.34)	99
No. of major intersections crossed		
To school, mapped	6.44 (3.00; 9.62)	99
To school, shortest path	7.30 (3.00; 10.46)	99
From school, mapped	6.26 (3.00; 9.36)	99
From school, shortest path	7.16 (3.00; 10.47)	99
Route directness		
To school, mapped	0.64 (0.66; 0.14)	99
To school, shortest path	0.67 (0.68; 0.13)	99
From school, mapped	0.61 (0.60; 0.14)	99
From school, shortest path	0.64 (0.65; 0.15)	99
Central city		
Route distance, m		
Home to school, mapped	1636.00 (1362.00; 896.32)	40
Home to school, shortest path	1633.00 (1303.00; 958.48)	40
School to home, mapped	1812.00 (1516.00; 1000.37)	40
School to home, shortest path	1757.00 (1470.00; 932.77)	40
Proportion of segment overlap		
To school	0.59 (0.66; 0.35)	40
From school	0.42 (0.42; 0.32)	40
No. of major intersections crossed		
To school, mapped	11.65 (6.50; 12.44)	40
To school, shortest path	7.30 (3.00; 13.07)	40
From school, mapped	10.10 (5.50; 11.50)	40
From school, shortest path	13.10 (7.50; 13.28)	40
Route directness		
To school, mapped	0.69 (0.69; 0.11)	40
To school, shortest path	0.70 (0.71; 0.11)	40
From school, mapped	0.62 (0.61; 0.14)	40
From school, shortest path	0.64 (0.67; 0.16)	40
Inner suburbs		
Route distance, m		
Home to school, mapped	1457.00 (1227.00; 909.85)	59
Home to school, shortest path	1380.00 (1094.00; 878.31)	59
School to home, mapped	1473.00 (1228.00; 923.97)	59
School to home, shortest path	1399.00 (1094.00; 900.90)	59

Continued

We performed all statistical analyses using R version 2.15.0 (R Foundation, Vienna, Austria). Shapiro–Wilk tests indicated nonnormality for all variables. We used the Wilcoxon signed-rank test to test for difference between respondent-mapped and shortest-path estimates of all measures, overlap index excepted. We used univariate description to examine route overlap. The home-to-school and school-to-home trips of children who walked and were driven were studied separately. We repeated the analyses for subsamples located within Toronto's older central city neighborhoods and its inner suburbs. Older central city neighborhoods have a larger supply of diverse transit options (e.g., bus, streetcar, subway), and higher rates of use of active modes for work and school travel, than the inner suburbs. For walkers, we used the Mann–Whitney U test to examine differences in overlap and route directness between central city and inner suburban samples.

RESULTS

Data loss (missing spatial or demographic data) and exclusion of modes with small numbers or modes requiring specialized network data—transit of any kind (n = 29), school bus (n = 32), bicycle (n = 52), or other (n = 16)—produced an initial sample of 759 children, aged 9 to 13 years in grades 5 and 6 (n = 343 boys, n = 411 girls, n = 5 gender unreported). We excluded cases in which the mode switched between the to- and from-school trips to ensure that the same respondents were included in both the to-school and from-school analyses. Drive trips farther than 5 kilometers (n = 5) were excluded; inspection revealed outlier cases in which children were driven long distances for idiosyncratic reasons. The final sample of 660 (75% of the original sample of 881 child participants) included 561 (85%) children who walked and 99 (15%) children who were driven. The sample data are provided in Tables 1 and 2. Results are summarized for walkers first, then for children who were driven (Table 3).

The degree of discordance illustrated by the O index was remarkable. Of walkers, 50% had O values of $O_n(to) \le 0.59$ and $O_n(from) \le 0.56$. The median value of the O index (walkers) was lowest for inner suburban trips

TABLE 2—*Continued*

Proportion of segment overlap		
To school	0.75 (0.92; 0.29)	59
From school	0.71 (0.87; 0.31)	59
No. of major intersections crossed		
To school, mapped	2.92 (2.00; 4.58)	59
To school, shortest path	3.05 (2.00; 4.93)	59
From school, mapped	3.66 (2.00; 6.47)	59
From school, shortest path	3.14 (2.00; 5.10)	59
Route directness		
To school, mapped	0.61 (0.62; 0.14)	59
To school, shortest path	0.65 (0.65; 0.15)	59
From school, mapped	0.61 (0.60; 0.14)	59
From school, shortest path	0.65 (0.65; 0.15)	59

Note. Cases were excluded if distance > 5 km.

from school ($O_n = 0.36$) and highest for central city trips to school ($O_n = 0.62$). The proportion of shared route segments, irrespective of trip direction, appeared to be greater for children in central Toronto than in its inner suburbs (Table 1). Overall, the median value of the overlap index was higher for to-school than from-school trips.

Results of the Wilcoxon signed-rank test indicate difference in reported and shortest path–derived metrics for walkers (Table 3). Major intersection counts and route directness showed evidence of discord in the pooled sample. These global relationships changed with stratification by school location. When compared with the central city, we found greater evidence of route discordance—more effects with typically larger effect sizes—for the inner suburban sample (Table 3). The shortest-path method appeared to produce larger median distances (to and from) and evidence of typically more direct routes for the central city sample, whereas it produced the opposite effects for the inner suburban sample (Table 1). Overlap (*O* index) was typically greater in central neighborhoods (median = 0.61) than in the inner suburbs (median = 0.36; $U = 41\,232.5$, $P < .01$) for school-to-home trips only. We also found evidence of a difference between the median of the ratio of reported- to shortest-path RDI between central city and inner suburban samples for both to-school trips ($U = 22\,914.5$, $P < .001$) and from-school trips ($U = 22\,691.5$, $P < .001$).

For children who were driven, 50% had *O* values of $O_n(to) \le 0.85$, and $O_n(from) \le 0.67$. The median value of the *O* index was lowest for central city trips from school ($O_n = 0.42$) and highest for inner suburb trips to school ($O_n = 0.92$). When compared against any other group, walkers included, the shortest path appears to offer a closer approximation of reported route structure, in terms of shared segments, for children who were driven in the inner suburbs (Table 2).

The Wilcoxon signed-rank tests indicate difference in reported and shortest path–derived metrics for children who were driven, within the pooled sample (Table 3). Effect size was typically larger for children who were driven than for walkers. In the pooled sample, we found the largest effects for the school-to-home RDI and route distance (Table 3). We found strong evidence of discord in distance (to and from) and route directness (to and from) for the inner suburban sample, whereas evidence of discordance covered a broader set of structural variables (e.g., distance, intersections counts, and route directness) in the central city (Table 3).

DISCUSSION

We have presented troubling evidence of route discordance. Our main findings indicate statistically significant differences in route distance, directness, intersection counts, and overlap between reported and modeled routes. We showed that differences varied by primary travel mode (children who walked or were driven), school location (central city or inner suburban neighborhoods), and trip direction (to or from school). Effect sizes reported for distance were within the small to medium range, with an apparent increase in magnitude in suburban locations for walkers and children who were driven. The presence of modest distance effects is noteworthy and should be given consideration in future research.

Concern about difference in distance alone is insufficient. Where these errors occur and the types of social and built environments experienced by children and adults in places excluded from modeled routes could also impact school travel mode choice. Shortest paths have been used to structurally define route-focused areas within which the BE is objectively measured.[26,27,30] Evidence of discord for major intersection counts and route directness offers insight into the presence of method-dependent uncertainty in the production of shortest-network-path route-based environmental data. As others have discussed,[38,39] this kind of measurement problem can produce inaccurate attribution of context to a health behavior or outcome. Although we are not the first to suggest that the shortest route may not be the actual route taken,[28,30,40,41] our work provides strong statistical evidence for reconsidering the empirical validity of shortest-path estimation as a method to model a child's to- or from-school route.

Some of the possible conceptual explanations for discordance are a child's social network, her or his extracurricular activities before or after school, or household errands (i.e., the shortest direct route between home and school ignores intervening activity locations). The shortest path might not attenuate perceived or objective risk of injury or fatality. Institutional mechanisms could also affect route selection. In the United Kingdom, for example, statutory walking distance, used to assess eligibility for free transport, may deviate from the shortest path on the basis of route safety.[42] Schools in Toronto have also experimented with signed school travel routes designed to address safety concerns.[43]

With regard to spatial behavior, consider that for an actual route to match a shortest route, children and their adults would need to

TABLE 3—Route Discordance Analysis Results, Drawn Routes versus Shortest-Path Estimates: Built Environment and Active Transportation Project; Toronto, Ontario, Canada; Spring and Fall 2011

Variable	*Z*	*r*	No.
Children who walked			
Home-to-school route distance, m	−0.46	0.01	561
School-to-home route distance, m	1.16	0.03	561
No. of major intersections crossed, to school	−4.79***	0.14	561
No. of major intersections crossed, from school	−4.76***	0.14	561
Route directness to school	−2.40**	0.08	501
Route directness from school	−2.84**	0.09	503
Central city			
Home-to-school route distance, m	−1.87*	0.07	359
School-to-home route distance, m	−2.40**	0.09	359
No. of major intersections crossed, to school	−0.26	0.01	359
No. of major intersections crossed, from school	−0.49	0.02	359
Route directness to school	−5.09***	0.20	322
Route directness from school	−5.42***	0.21	320
Inner suburbs			
Home-to-school route distance, m	−3.92***	0.20	202
School-to-home route distance, m	−3.33***	0.17	202
No. of major intersections crossed, to school	−6.87***	0.34	202
No. of major intersections crossed, from school	−6.51***	0.32	202
Route directness to school	−1.79**	0.09	179
Route directness from school	−1.38	0.07	183
Children who were driven			
Home-to-school route distance, m	−2.98**	0.21	99
School-to-home route distance, m	−3.97***	0.28	99
No. of major intersections crossed, to school	−2.20*	0.16	99
No. of major intersections crossed, from school	−0.95	0.07	99
Route directness to school	−3.48***	0.25	99
Route directness from school	−4.05***	0.29	99
Central city			
Home-to-school route distance, m	−0.37	0.04	40
School-to-home route distance, m	−2.35**	0.26	40
No. of major intersections crossed, to school	−2.24*	0.25	40
No. of major intersections crossed, from school	−2.15*	0.24	40
Route directness to school	−0.71	0.08	40
Route directness from school	−2.24*	0.25	40
Inner suburbs			
Home-to-school route distance, m	−3.18***	0.29	59
School-to-home route distance, m	−2.98**	0.27	59
No. of major intersections crossed, to school	0.18	0.02	59
No. of major intersections crossed, from school	−1.04	0.10	59
Route directness to school	−3.51***	0.32	59
Route directness from school	−3.21***	0.30	59

Note. All tests compared route structure variables mapped versus shortest path. r is the absolute value of Wilcoxon effect size.
*P < .05; **P < .01; ***P < .001.

make route-choice decisions using guiding principles that closely match shortest-path assumptions—that is, economic rationality over a satisficing alternative.[44] Moreover, detailed environmental knowledge is necessary—perhaps full information, with a view to constructing, by comparison, the shortest of all possible routes. An alternative, of course, could involve, where available, application of Internet mapping (e.g., Google Maps). In that case, too, however, the underlying motive, beyond achieving a way-finding objective, could be cost minimization.

Beyond conceptual or policy-driven explanation, details regarding shortest-path estimation are often left unreported.[26–32] Reporting how road direction, turn restrictions, and impedance (generalized cost of travel through the network) are conceptualized and implemented is important for reproducibility. Thinking about differences in route modeling by mode is also necessary. There has been some discussion of representation of access points at the school end.[28–30] Consensus is absent on the scale of representation of school and home locations; children are also likely to access a school's parcel, and then the building itself, using different access points over time.

Data from the descriptive analysis suggest longer shortest network paths than reported routes for walkers and a positive difference in median route lengths for children who are driven. These relationships persist with sample stratification. For walkers, this difference is explained by the anchoring of the school access point to each school's main entrance. In the absence of information on the school entrance location, the shortest-path algorithm finds a route ending at the primary entry point of the school's main building. With the exception of Panter et al.,[30] who conducted a field survey of potential school access points, route-based studies typically assign the same school access point to all students.[26–28,31] For children who were driven, (1) car trips were pushed (by the algorithm) onto major, cost-minimizing arterials that were less reflective of mapped routes, but where posted speeds are higher, and (2) by focusing on the school-to-home trip only, the shortest-path algorithm did not search through intervening destinations that would have produced longer mapped routes.

What about global positioning system (GPS) data collection? Duncan and Mummery,[40] using different metrics and a smaller sample, empirically tested the efficacy of shortest-path analysis using GPS. Our study, however, contributes new evidence using different instruments, metrics, and a sample that is approximately 10 times larger. Our study also demonstrates directional, modal, and spatial differences in the statistical properties of route discordance. Researchers and practitioners have agreed that not all of the problems with GPS have been solved, from technical issues to respondent adherence.[45,46] We have demonstrated that, for studies focused on a specific type of trip, a map-based approach, with subsequent route digitizing using GIS, may show greater promise than the shortest-path method.

Limitations

Limitations include the possibility that the research attracted fewer driving households than expected. Data from a separate regional travel survey indicate walking rates in 2006 for the City of Toronto of 48.1% in the morning and 54.8% in the afternoon.[2] Findings for children who were driven could, in part, be a sample-size problem. Field assistants were instructed during recruitment about the risk of alienating drivers through use of exclusionary language or promotion of active transportation modes. The study protocol also made it clear that the research was not about studying walking or getting more students to walk per se. As is typical of school travel research, participants reported on their usual route. Despite instruction ahead of time, and the use of image maps to help respondents with orientation, the use of reported mapped routes relies on each respondent's conceptualization of their routes as cartographic objects.

Conclusions

In the absence of reported or GPS survey shortest paths, shortest-path algorithms, embedded in GIS software, are often used to estimate school travel routes in studies designed to identify BE correlates of school travel-mode choice. The shortest path may not reflect the actual route taken to or from school by children and youths.[28,30,40] Statistical comparison of route-based metrics estimated using respondent-mapped (reported) and GIS-estimated shortest-path routes to and from school has indicated problems with the empirical validity of the shortest-path approach. We showed that discord between reported- and shortest-path route variables varied by trip direction (to or from school), travel mode (walked or driven), and school neighborhood location (central city or inner suburbs). Reliance on the shortest-path approach to understanding BE influences on school travel-mode choice has conceptual and empirical limitations. ■

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This article was accepted December 5, 2012.

Contributors

R. N. Buliung conceptualized the article and took the primary role in the study design, analysis, and writing. K. Larsen was involved in the study design, GIS estimation, and writing of the article. G. E. J. Faulkner was involved in the study design, analysis, and writing of the article. M. R. Stone was instrumental in field data collection.

Acknowledgments

The Built Environment, Obesity and Health Strategic Initiative of the Heart and Stroke Foundation and the Canadian Institutes of Health Research provided funding for this research. R. N. Buliung and G. E. J. Faulkner were the co–principal investigators.

We also recognize the dedication of our child and adult participants and our research assistants.

Human Participant Protection

This study was approved by the Research Ethics Board of the University of Toronto and the Toronto District School Board Ethics Review Board.

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