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Economics of Interventions to Increase Active Travel to School: A Community Guide Systematic Review

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Abstract

Context: The number of children who bicycle or walk to school has steadily declined in the U.S. and other high-income countries. In response, several countries responded in recent years by funding infrastructure and non-infrastructure programs that improve the safety, convenience, and attractiveness of active travel to school. The objective of the present study is to synthesize the economic evidence for cost and benefit of these programs.

Evidence acquisition: Literature from inception of databases to July 2018 were searched, yielding 9 economic evaluation studies. All analyses were done during September 2018 through May 2019.

Evidence synthesis: All studies reported cost, 6 studies reported cost benefit, and 2 studies reported cost effectiveness. The cost-effectiveness estimates were excluded based on quality assessment. Cost of interventions ranged widely, with higher cost reported for the infrastructure-heavy projects from the U.S. ($91,000 to $179,000 per school) and United Kingdom ($227,000 to $665,000 per project). Estimates of benefits differed in inclusion of: improved safety for bicyclists and pedestrians, improved health from increased physical activity, and reduced environmental impacts due to less automobile use. The evaluations in the U.S. focused primarily on safety. The overall median benefit to cost ratio was 4.4:1.0 (IQR=2.2:1–6.0:1, 6 studies). The 2-year benefit–

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cost ratios for U.S. projects in California and in New York City were 1.46:1 and 1.79:1, respectively.

Conclusions: The evidence indicates that interventions that improve infrastructure and enhance the safety and ease of active travel to schools generate societal economic benefits that exceed the societal cost.

CONTEXT

Research has shown that motorized transport that displaces walking and bicycling contributes to reduced physical activity[1] and pollution[2,3] that lead to poor health outcomes,[4,5] other economic costs,[6] and reduced quality of life.[7] In the case of transport of children to and from schools, motorized modes have proliferated, even for short distances that were previously walked or bicycled. In 1969 in the U.S., 41% of children in kindergarten through eighth grade (approximately age 5–14 years) lived within 1 mile of school and of these, 89% usually walked or bicycled to school.[8] In 2009, the percentage of kindergarten through eighth grade children who lived within 1 mile of school declined to 31%, and only 35% of them usually walked or bicycled to school.[9] A recent survey finds that of the 15 million children who lived within 1 mile of their school, 31% walked or bicycled to school, 20% took the school bus, 0.8% took public transport, and the remaining 48% traveled by private vehicle.[10]

One among many factors contributing to the decline in active travel to school is the greater distance from homes to schools due to school siting practices that locate larger schools at the outskirts of communities.[11,12] Among the barriers identified from surveys of U.S. parents in 2005, the distance between the home and school was the most prominent, followed by concerns about the dangers of traffic, inclement weather, and crime,[13] with more recent studies finding similar results.[14,15]

Active Travel to School (ATS) interventions aim for children who live within 1–2 miles of schools to walk or bicycle to school by making routes to school safer and easier to use and promoting their use. In the U.S., the largest and most prominent of these interventions were those funded and promoted under the Safe Routes to School (SRTS) program of the Department of Transportation. In 2018, the Community Preventive Services Task Force (CPSTF), an independent, non-federal panel of population health experts, recommended interventions to increase active travel to school. The recommendation was based on a systematic review of evidence that showed ATS interventions increased walking among students and reduced risks for traffic-related injury.[16] The present study is a systematic review of the economic evidence for the cost and economic benefit of ATS interventions implemented in the U.S. and other high-income countries as defined by the World Bank.[17]

EVIDENCE ACQUISITION

Concepts and Methods

The ATS interventions make it easier and safer for children to walk and bike to school by targeting the physical or social safety of common routes to school or by promoting safe travel behaviors. Interventions must include ≥1 of the following components, based on the Safe Routes to School model[18]:

1. engineering—improvements to the built environment infrastructure;
2. education—materials and activities to teach the importance of active travel;
3. encouragement—events and activities to promote active travel; and
4. enforcement—partnerships with law enforcement and others to ensure traffic laws are obeyed in school neighborhoods.

This study was conducted using established methods for systematic economic reviews approved by the CPSTF.[19] The team included subject matter experts on physical activity and active travel from various agencies, organizations, and academic institutions, in addition to members of the CPSTF and experts in systematic economic reviews from the Community Guide Office at the Centers for Disease Control and Prevention. Two reviewers independently screened the search yield, abstracted information from the included studies, computed economic estimates, and quality scored each estimate. Disagreements were resolved through discussions.

The present study asks what it costs to implement ATS interventions and what the economic benefits are that result from the intervention. Do the economic benefits due to intervention exceed the cost to implement?

This economic review framework in Figure 1 depicts how the intervention is expected to work and the pathways to economic costs and benefits. Moving from top left to the right, the targeted population includes students and their parents for whom walking or bicycling to school is feasible, plus other community residents who may use the routes for other purposes. All students and parents have multiple mode choices available to them to travel between home and school, including private automobiles, school bus, walking, bicycling, and public transit. The effective intervention leads to an increase in the proportion of students who choose the ATS mode (i.e., walking or bicycling), and a reduction in the proportions using other modes of travel, as was shown in the review of effectiveness.[16] Health improves from the increased physical activity of active travel and averted longer-term diseases associated with inactivity and excess weight. Each travel mode choice has particular private and societal costs that derive from monetization of effects on resource use, travel time, health, traffic-related injuries, and impacts on the environment. Where these costs are reduced because of the intervention are the economic benefits due to intervention. ATS interventions also improve the social environment (e.g., a Walking School Bus program; safety in numbers) and the built environment's physical safety, thereby reducing injuries for both current and new users of the routes.

The economic costs and conequences of the interventions are shown at the bottom of Figure 1. At the bottom left, economic evaluations of these interventions capture the cost to implement the intervention, which includes planning, infrastructure changes, education, promotion, and enforcement activities. The components marked with asterisks are expected to be drivers of the magnitude of estimates. At the bottom right are the monetized and other benefits due to intervention. The total societal monetized benefit of the intervention is therefore the sum of the following elements of costs associated with all individuals and their travel mode choices post intervention minus the costs at baseline: physical resources and travel time, environmental impacts, near and longer-term healthcare costs, and injuries and fatalities. All the components of benefits are expected to be drivers of the magnitude of the estimate, and are therefore marked with asterisks. The framework in Figure 1 postulates that ATS interventions cause a shift toward cheaper, safer, environmentally friendlier, and healthier ATS modes and away from the use of private automobiles and busing.

Quality of estimates.

Quality assessment of the economic evidence follows methods developed by the Community Guide for systematic economic reviews.[19] In general terms, individual estimates from the studies are assigned a quality score of good, fair, or limited, based on assessments within each of 2 domains. First, quality is assessed based on the domain of capture; that is, how well an economic estimate captures the drivers from among its components. A driver of an estimate is a component that contributes substantially to its magnitude. Second, quality is assessed based on the domain of measurement, which is the appropriateness of methods used by the study to measure and value the estimates. The final quality assignment is the lower of the 2 assigned quality scores. The quality of a composite estimate such as cost benefit is the lower of quality assigned to its individual cost and benefit parts. Limited quality estimates are excluded from the body of evidence.

The quality assessment process just described in general terms was adapted within a quality assessment tool developed for the specifics of the present review, and is available in the Appendix. Within the domain of capture, engineering and education or encouragement were considered drivers of intervention cost. The drivers of benefits were costs of private automobile use, injuries and fatalities, travel time, healthcare cost related to physical inactivity and body weight, and the health and other impacts of congestion, pollution, and greenhouse gases. Note these were the drivers also identified in Figure 1. Within the domain of measurement, the quality of benefit estimates and cost estimates were additionally assessed in the following listed areas along with what are deemed appropriate for the present intervention and review. Limitation points were assigned for departures from what is appropriate.

1. Perspective: Societal is appropriate.
2. Population: Students and their parents that are targeted must live within a distance from their school that is walkable or bikeable. Sample size of ≥100 in school enrollment.
3. Source of benefits: Economic benefits must be derived from observed changes in travel mode or improved safety.
4. Time horizon for benefits: 10-year horizon is appropriate for infrastructure-heavy projects.
5. Model inputs, parameters, and valuation: The methods used for cost or benefit estimation are transparent or peer-reviewed. Appropriate valuation of resources and effects are based on local conditions.

Opportunity is provided in the assessment process to assign a fatal flaw that automatically scores an estimate as “limited” quality. A fatal flaw is some feature of the estimate that almost certainly causes it to severely misrepresent the true cost or benefit of the ATS intervention.

All monetary values are in 2019 U.S. dollars, adjusted for inflation using the Consumer Price Index,[20] and converted from foreign currency denominations using purchasing power parities.[21] All analyses were conducted during September 2018 through May 2019.

Search Strategy

Peer-reviewed and gray literature were searched for economic evaluations. Criteria for inclusion were as follows: met the definition of the intervention, conducted in a high-income country.[17] written in English, and included ≥1 economic outcomes described in the research questions.

A formal search was conducted within PubMed, Scopus, Cochrane, National Transportation Library, National Technical Information Service, and EconLit for papers published through July 2018. Informal searches were also conducted for reports from governments and non-government organizations using the Google and Google Scholar search engines. Finally, citations from another review[22] and reference lists in included studies were screened and subject matter experts were consulted for additional studies. The detailed search strategy is available on The Community Guide website.[23]

EVIDENCE SYNTHESIS

Results

A total of 1,745 papers were screened, yielding 9 studies[24–32] for inclusion (Appendix Figure 1). Three papers were consulted for additional information on the included studies, 2 studies[33,34] related to 1 primary study[28] and 1 study[35] related to another primary study.[25]

Table 1 provides an overview of the studies. Three studies were from the U.S.,[28,29,31] and all 3 evaluated projects within the SRTS program. Of the 6 studies outside the U.S., 2 were from the United Kingdom (UK),[24,32] 3 from Australia,[25–27] and 1 from Canada.[30] Two studies[26,27] were purely education and promotion interventions with no infrastructure and the remaining ranged across heavily infrastructure,[24,29,32] a mix of infrastructure and promotion or education,[28,31] and mostly promotion or education with small infrastructure.[25,30]

Table 1 provides additional details regarding the projects, schools, and students that were targeted. The number of projects and schools included in the U.S. studies of SRTS interventions were: 48 projects involving 53 schools in the national study,[28] 125 projects involving 350 schools in the California study,[31] and 124 schools in the New York City study.[29] The Canadian study[30] involved 13 schools and the 2 UK studies[24,32] evaluated a total of 12 different projects but did not report the number of impacted schools. Most of the interventions were for elementary or primary school populations. Hence, the number of interventions evaluated, from an evidence perspective, constitutes a much larger number than a simple count of the included studies. The U.S. national study of the SRTS program[28] reported a median student body of 675 per participating school and the study of SRTS in California[31] reported that 53% of projects undertaken were associated with student populations in excess of 1,000. Table 1 shows that the majority of studies reported the change in travel modes due to intervention, in particular the increase in travel by walking or bicycling following the intervention. The cost of intervention was reported by all 9 studies. Two studies in the U.S.[29,31] and 4 studies outside the U.S.[24,25,30,32] etimated benefit–cost ratios, and 2 studies from Australia[26,27] estimated cost per disability-adjusted life year averted.

Intervention cost.

The cost of the intervention from the 9 studies are provided in Table 2, along with components included in the estimate and the quality of the estimate. Cost per school or cost per project is shown, wherever possible. Two[27,30] of the estimates for intervention cost were of good quality and 7 studies[24–26,28,29,31,32] were of fair quality. The most frequent reasons for assignment of quality limitations were: reporting funded amount without details by components or matched funding from local sources, failure to include cost of volunteer and in-kind contributions, and failure to include infrastructure component in some studies and non-infrastructure in other studies.

The grand mean of cost per school from the 3 U.S. SRTS studies was $152,243. The mean cost per school was similar for the 48 projects (53 schools) in California[31] and for the 125 projects (350 schools) in multiple states,[28] at $186,576 and $179,012, respectively. On the other hand, the SRTS program in New York City[29] cost $91,140 per school. The difference in cost may be due to the relatively less infrastucture-heavy components in the New York City projects, which primarily improved sidewalks and crossing areas.[29] By contrast, the multistate study[28] and the California study[31] evaluated projects that included some or all of the following in intervention cost: sidewalk construction or improvement, crosswalks, traffic calming measures, and bicycle paths and facilities. Projects in the UK had even greater infrastructure components than the U.S. SRTS projects, which may account for their higher cost of $226,753[24] and $664,864[32] per project.

Benefits of intervention.

Table 3 provides the quality assessment of the estimates for benefits reported by 8 studies.[24–27,29–32] The estimates are not presented in Table 3 because the basis of the estimates differed widely in both time horizon and in geographic scope; instead, the estimates and methods behind them are described in the Cost Benefit section and in Table 4. There were 4 good quality estimates for benefits[24,25,30,32] and 2 that were fair quality.[29,31] The most frequent reasons for assignment of quality limitations were: benefits based only on 1 impact such as injuries or fatalities, long time horizon of 30 or 50 years, short time horizon of 1 year, ATS change based on self-report or counts of users observed on routes, and ATS change included adults. Two estimates of cost per disability-adjusted life years averted from 2 studies[26,27] were assigned limited quality because they accounted for benefits from from averted obesity only, and was considered a fatal flaw for the present review. These 2 limited quality estimates were excluded from further consideration.

Cost benefit.

Estimates along with assessed quality for cost benefit and its component parts are shown in Table 4 from 2 U.S. studies[29,31] and from 4 non-U.S.[24,25,30,32] studies. One estimate[30] is rated as good for cost-benefit and the remaining estimates are all of fair quality. Table 3 also shows the sources and methods used to estimate the intervention cost and economic benefit, along with the geographic area and time horizon. The median benefit to cost ratio reported by the 6 studies was 5.8:1 (IQR=3.9:1–9.1:1). The study of the SRTS program in California[31] reported a benefit–cost ratio of 0.74 over a very short 1-year time horizon and the study of the SRTS program in New York City[29] reported a benefit–cost ratio of 22.1:1 over a very long 50-year time horizon. Available information allowed the present reviewers to re-compute the benefit to cost ratios based on a 2-year time horizon for these 2 studies. For the recomputed estimates, the median benefit to cost ratio from the 6 studies was 4.4:1 (IQR=2.2:1–6.0:1). The median benefit to cost ratio for the infrastructure-heavy projects from the U.S.[29,31] and those from the UK[24,32] was 3.5:1 (IQR=1.7:1–6.4).

DISCUSSION

This study reviewed the evidence for the cost and the economic benefits from ATS interventions. The cost to implement ATS interventions varied widely with higher costs observed for projects that included new or improved infrastructure. Estimates of societal benefits due to ATS interventions also varied. Benefits estimated in the U.S. studies[29,31] were derived from improved safety that reduced traffic-related injuries and fatalities. The focus of the U.S. SRTS programs on safety fits with the prominent placement of safety as an objective of the federal legislations that funded SRTS programs nationwide.[36] Studies from outside the U.S.[24,25,30,32] included benefits of reduced injuries and a range of additional environmental and health impacts of reduced motorized transport and increased walking and bicycling. For the aforementioned reason, the benefit–cost ratios from studies outside the U.S. tended to be larger than those for U.S. ATS interventions. These variations aside, the evidence showed that the economic benefits of ATS interventions exceed the cost both in the U.S. and in the other high-income countries.

The issues revealed in the present review regarding the appropriateness of conceptual framework, measurement, modeling, and risks of bias in the estimation of cost and benefit are not confined to ATS interventions. They have been recognized in other systematic and critical reviews of the ATS[37] and larger literature on built environments, active travel, and physical activity.[38–42] The issues and criticisms fall into 2 broad areas: first, the framework of what is included in the estimates and the causal pathways between them; second, with regard to methods and measurement. The results from the present review are examined in light of the key issues raised in the aforementioned critical reviews.

The expert review and commentary by McDonald et al.[37] identified the plausible benefits from ATS interventions in the U.S. All elements of benefits identified in the expert review are captured in ≥1 studies included in the present review, except for the benefits from averted hazard busing due to improved safety. Hazard busing, estimated to cost $100 and $500 million annually, is bus service provided in the U.S. for children who may live close to schools but where it is physically or socially unsafe to walk or bicycle to school. Doorley and colleagues[39] and Mueller et al.[40] note that evaluations differed in inclusion of health effects, whether from physical activity, ambient pollution inhalation, and risk of collision, and whether they included the costs of morbidity or mortality or both. They conclude in their syntheses that the health benefits were greatest from increased physical activity followed by injuries prevented by improved infrastructure and possibly "safety in numbers." Further, Muller and colleagues[40] found the health benefits from physical activity far outweighed any harms from inhaled pollutants or injuries from increased active travel. The substantial part of benefits estimated for ATS interventions in the present review were derived from averted healthcare costs. The U.S. SRTS studies that were focused on the injuries and fatalities averted monetized those benefits based on associated healthcare costs for averted morbidity, and funeral costs[29] or value of statistical life[31] for the rare fatality. Based on observations made in the critical reviews, the U.S. SRTS evaluations in the present review may have underestimated the benefits by not accounting for increased physical activity's impact on disease and healthcare costs averted. On the other hand, all the studies in the present review that were from outside the U.S. included the monetized benefits from increased physical activity due to ATS, albeit using the different methods and calculations, as shown in Table 4. The UK studies in the present review followed methods similar to the WHO Health Economic Assessment Tool (HEAT),[43] which derives health benefits of physical activity from averted disease-related mortality. A monetary value is assigned to each kilometer of active travel by the Australian study,[44] based in turn on estimates from the New Zealand Department of Transport, and also by the Canadian study,[30] based on estimates drawn from a transport research institute.[6] These differences in methodologies may explain variations in reported cost–benefit estimates.

Two recent methodologic reviews of active travel evaluations[38,41] describe far knottier problems faced by researchers who work with what are non-experimental observational study designs, namely the difficulties in correctly estimating the magnitude of travel mode shift, change in physical activity, and even identifying the target population of interest. The reviews note that evaluations of extensive infrastructure interventions are more likely to correctly estimate change in total physical activity by measuring the range of daily travel modes and behaviors over a greater area, whereas smaller projects may conflate the true change in physical activity with activity displaced from elsewhere. The possibility of conflation is especially problematic where active travel change is measured from simple observed counts of users along a single route or pathway.[38] The evaluations of ATS interventions in the present review may not as susceptible to these pitfalls, but they are not immune. The target population of school students in ATS is quite well defined and there is a clear destination and purpose for school travel. Students have to get to and from school by some travel mode or other, and any reduction in 1 mode must show up as an increase in some other mode. Therefore, a show of hands in class or self-report from a student or parents survey, as done in many of the studies included in the present review, should be an acceptable measure of mode shift for ATS interventions. Further, the U.S. SRTS evaluations that were included in the present review assessed the monetized benefits from observed[29] or estimated[31] reductions in injuries and fatalities and not directly from change in active travel. On the other hand, the issue of physical activity possibly displaced from elsewhere is certainly a limitation of the ATS evaluations from the UK,[24,32] which estimated physical activity from the observed pre to post counts of walkers and bicyclists on improved or new paths, and included both children and adults.

The critical reviews[40,42] also called for more attention to equity considerations in the evaluation and comparison of active travel interventions. In this regard, the SRTS programs in U.S. urban areas, with their focus on both physical and social safety, are likely to have substantial equity impacts. Densely populated urban districts in the U.S., with large representation of minority race/ethnicity and low-income populations, are more likely to walk or bicycle to school. These children have been seen to take longer than the shortest routes to avoid hazardous streets, sidewalks, graffiti, and crime.[45] The SRTS programs can benefit these children who may very well have no choice but to walk or bicycle to school.

The quality assessment tool used in the present review scored each cost and benefit estimate based on what conceptually important components were captured and how the estimates were measured. Limitation points were assigned to each estimate for each shortfall within a number of areas including target population and size, price used to monetize value of resources, accuracy of observed outcomes (active travel or mode shift) from which benefits are modeled, time horizon, and others. The elements enumerated from the quality assessment tool cover most but not all of the issues raised in the recent critical reviews of the literature. The large number of estimates that received a fair rather than good rating indicate it is rare that every one of the difficulties and issues raised by the critical reviews are successfully addressed by an ATS economic evaluation.

Limitations

The number of people who can reasonably choose an active mode of travel to school and the proportion that actually did so at baseline and post intervention are needed to evaluate the effectiveness of ATS interventions.The omission by U.S. studies of other health and environmental benefits from ATS interventions substantially understates the plausible total economic benefits. Separate estimates for the components of economic benefits from ATS interventions should be reported. It would be useful from the perspective of policymakers from different government agencies to know what the contribution to total benefits were from: traffic injuries/fatalities, pollution, traffic gridlock, public safety and crime, physical activity, overweight and obesity, and academics and learning. Some components may have greater significance to their mission and objectives than others.

CONCLUSIONS

Evidence indicates that interventions that improve infrastructure and enhance the safety and ease of ATS generate societal economic benefits that exceed the cost to implement these interventions.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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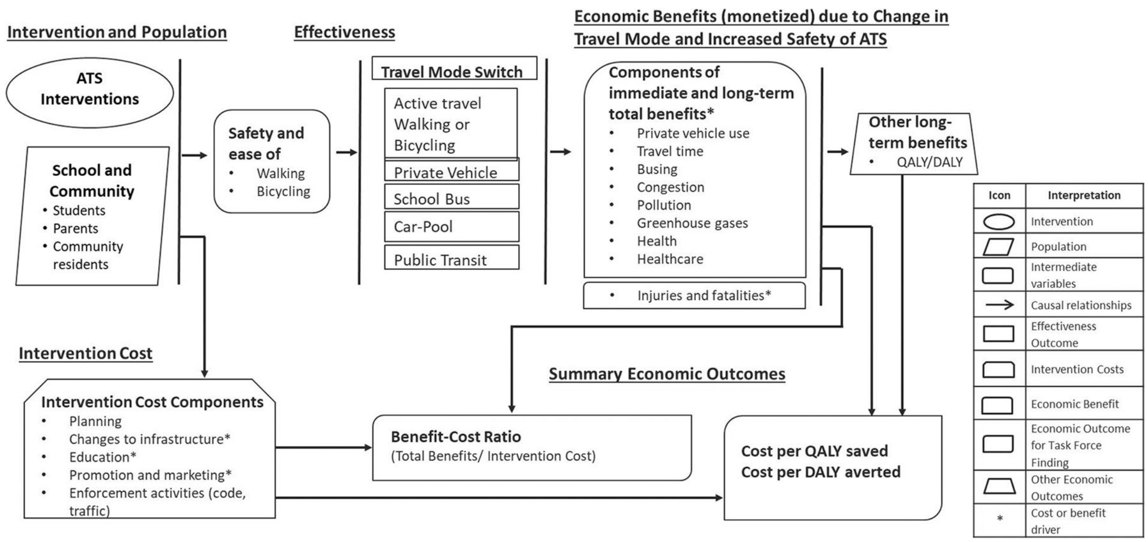

Figure 1.

Pathways to economic costs and benefits of ATS interventions.

ATS, active travel to school; QALY, quality adjusted life year; DALY, disability adjusted life year.

Table 1.

Characteristics of Study, Intervention, and Target Population, Intervention Effect and Type of Economic Analysis

Study author (type)	Country (area)	Primary intervention component and focus	Program name (level of school	Projects (schools), n	School enrollment	Effect of intervention in travel mode	Type of economic analysis
Moudon 2012[28,33,34] (Gov)	U.S. (WA, WI, MS, FL)	Infrastructure (25%) and mixed infrastructure and non-infrastructure (75%) projects. No outcomes beyond ATS.	SRTS (elementary and middle)	48 (53)	Median 675 (IQR =319 to 962)	Pre- and post-project reports of walking or bicycling to school. Stewart 2014 reports overall ATS increased by 36% (from 12.9% to 17.6%) at 53 schools representing 48 projects with complete data.	Cost
Muennig 2014[29] (Journal)	U.S. (NYC)	Improved infrastructure for safety. Focused on pedestrian and bicyclist safety.	SRTS (NR)	NR (124)	NR	+11% ATS 33% to 44% injury reduction.[46]	Cost-benefit
Orenstein 2007[31] (Gov)	U.S. (CA)	Mix of infrastructure and non-infrastructure. Focused on pedestrian and bicyclist safety.	SRTS (elementary and middle)	125 (350)	By project: ≥1,000 52.8%	Scenario 1: +25% ATS Scenario 2: +50% ATS Increase in ATS in SRTS locations based on evaluations of the California SRTS program.[47,48] and reports from individual schools or projects.	Cost-benefit
Davis 2014[24] (Gov)	UK (Selected projects)	Infrastructure projects including new bikeways and pedestrian pathways. Health outcomes from physical activity and environmental impacts.	Links to Schools. Tackling the School Run. (NR)	9 (NR)	NR	Median of new users reported from multiple projects: Bicyclists 70; Pedestrians 268. Median change in trips for children: Bicycle +98%, Walking +5%	Cost-benefit
Fishman-Ker 2011 a,b[25,35] (NGO)	Australia (Queensland)	School and street-level infrastructure ATS projects. Health outcomes from mode shift away from private automobiles and environmental impacts.	Active School Travel (primary)	NA (470)	Mean 400	Car use reduced 10% resulting in increase of 25% for bicycling and increase of 75% for walking. Effect estimate informed by experience in City of Brisbane.[35]	Cost-benefit
Moodie 2009[26] (Journal)	Australia (All)	Non-infrastructure Walking School Bus program. Focused on averted obesity.	Walking School Bus (primary)	350 (1,400)	11.2 participants per school	Baseline to post participation rates based on data from VicHealth, Victoria, Australia.[49] Wide range assumed for increase in number of students walking to school due to lack of data to identify new participants.	Cost per DALY
Moodie 2011[27] (Journal)	Australia (All)	Non-infrastructure educational and promotional. Focused on averted obesity.	Travel SMART (primary)	NR (3,870)	Whole of school Mean 247; Curricular Mean 1,620	Pre and post parent survey indicated following percentage point increases: Walking increased 2.4 Bicycling increased 12.1	Cost per DALY
Sustrans 2014[32] (Gov)	UK (Selected projects)	Infrastructure ATS projects including new bikeways and pedestrian pathways. Health outcomes from physical activity and environmental impacts.	Linking Communities (NR)	3 (NR)	NR	Increase from almost no child users to 2009 and 8,318 for 2 projects, respectively.	Cost-benefit

Study author (type)	Country (area)	Primary intervention component and focus	Program name (level of school	Projects (schools), n	School enrollment	Effect of intervention in travel mode	Type of economic analysis
University of Toronto 2016[30] (Gov)	Canada (Toronto)	Incentives, promotion, and education with small infrastructure. Health outcomes from physical activity and impact of reduced private automobile use.	School Travel Planning (elementary)	NA (13)	Mean 534	Changes in mode of travel to school collected from 13 participating schools using “hands-up surveys” of students. Car use −3.5%; Walking +1%; Bicycling +1.5%; Public transit +3.5%	Cost-benefit

Gov, government; NGO, non-government organization; SRTS, Safe Routes to School; WA, Washington; WI, Wisconsin; MS, Mississippi; FL, Florida; CA, California; NYC, New York City; ATS, Active travel to school; Primary, grades 1 through 5 or 6 in UK and grade 1 through grade 6 or 7 in Australia; Elementary, grades 1 through 5 in U.S.; Middle, grades 6 through 8 in U.S., DALY, disability adjusted life year; NR, not reported; NA, not applicable; UK, United Kingdom.

Table 2.

Intervention Cost: Estimates, Components, and Quality of Estimates

Study	Cost per school	Quality of estimate	Components of intervention cost				
			Education	**Enforcement**	**Promotion**	**Other**	**Infrastructure**
Moudon 2012[28,33,34]	Median $154,959 Mean $179,012	Fair	Education activities	Patrol	Walk/Ride days	WSB	Sidewalk, crosswalk, signage
Muennig 2014[29]	$91,140	Fair	Education programs	No	No	No	Sidewalk improvement and construction, safety improvements at dangerous intersections
Orenstein 2007[31]	$186,576	Fair	No	No	No	No	Sidewalk, traffic calming, signals, crosswalk, bicycle paths
Davis 2014[24]	$226,753 per project	Fair	No	No	No	No	Modified or new roadways, bikeways, walkways, sidewalks, crossings, signals
Fishman-Ker 2011[25,35]	$12,253	Fair	Safety education and skills	Police presence	Walk/ride day	WSB, maps, transition to high school	School bike cages. Study does not include the cost of street-level infrastructure changes in intervention cost, with the argument that such changes fall within the purview of public works and not school systems.
Moodie 2009[26]	$12,464	Fair	Volunteer training, kits	No	Walk/ride days, Newsletter	WSB, Government coordinators, School liaisons, Volunteer time	No
Moodie 2011[27]	$2,529	Good	Teacher training, Teacher time	No	Special events	National and local government coordinators, School liaisons	No
Sustrans 2014[32]	$664,864 per project	Fair	No	No	No	No	New biking/walking path and bridges, modify/expand green corridor paths to enhance connectivity
University of Toronto[30]	$8,840 per project	Good	Bicycle training	No	Walk/ride days, Incentives	No	School bike racks, signage, pavement marking

NA, not applicable; WSB, walking school bus; No, component not included in estimate.

Table 3.

Intervention Benefits: Components, and Quality of Estimates

	Quality of benefits estimates		Components of benefits						
Study	**Quality of capture Quality of measurement**	**Overall quality**	**Private vehicle use**	**Travel time**	**Injuries or fatalities**	**Busing**	**Congestion**	**Pollution or greenhouse**	**Health-related**
Moudon 2012[28,33,34]	NA NA	NA	NA	NA	NA	NA	NA	NA	NA
Muennig 2014[29]	Fair Good	Fair	No	No	Yes	Yes	No	No	No
Orenstein 2007[31]	Fair Good	Fair	No	No	Yes	No	No	No	No
Davis 2014[24]	Good Good	Good	No	Yes	Yes	No	Yes	Yes	Yes
Fishman-Ker 2011[25,35]	Good Good	Good	Yes	Yes	Yes	No	Yes	Yes	Yes
Moodie 2009[26]	Fair Limited	Limited	No	No	No	No	No	No	Yes
Moodie 2011[27]	Fair Limited	Limited	No	No	No	No	No	No	Yes
Sustrans 2014[32]	Good Good	Good	No	Yes	Yes	No	Yes	Yes	Yes
University of Toronto 2016[30]	Good Good	Good	Yes	Yes	No	No	Yes	Yes	Yes

NA, not applicable; No, component not included in estimate; Yes, component included in estimate.

Table 4.

Benefit-Cost Ratio Estimates

Study Area, Country (n of schools)	Source for intervention cost	Source and method for benefits estimation	Time horizon for benefits	Cost	Benefit	B-C ratio	Quality of estimate
Muennig 2014[29] New York City, U.S. (124)	Funded amount for New York City. No details provided.	Focus on safety as stipulated in the federal statute.[36] Averted medical costs of student pedestrian injury reductions plus funeral costs, in the rare case of death. Injuries classed by severity[50] and associated costs drawn from CDC[51] and other sources	Scenario 1: 50 years Scenario 2: 2 years[b]	$11.30 mil $11.3 mil	$242 mil[a] $20.03 mil[a]	22.1:1 1.79:1	Fair Fair
Orenstein 2007[31] California, U.S. (214)	Funded amount from national SRTS project tracking database with information collected from state coordinators. Unclear if amount includes state and local matching funds.	Focus on safety as stipulated in the federal statute.[36] Modeled 1-year economic benefit of reduced pedestrian traffic injuries and fatalities rates in 125 SRTS locations compared to non-SRTS locations after increase in ATS in SRTS locations due to intervention.	Scenario 1: 1 year Scenario 2: 2 years[b]	$36.6 mil $36.6 mil	$27.2 mil $53.5 mil	0.74:1 1.46:1	Fair Fair
Davis 2014[24] Select projects, UK (9 projects)	No details. Likely the funded amount including any matching funds.	Averted healthcare cost from favorable long-term health outcomes due to increased walking and bicycling. Monetized value of reduced impacts on the environment due to reduced automobile use. Healthcare cost dominate most of the evaluations. Methods consistent with guidance provided by the UK Department for Transport,[52] and the health benefits of walking and bicycling as modeled with WHO's Health Economic Assessment Tool (HEAT).[43]	10 years	Mean $226,753	Mean $909,533	Mean 5.2:1 (All>1.0:1)	Fair
Fishman-Ker 2011[25,35] Queensland, Australia (470)	Brisbane City Council pilot program data[35] and allowance for development of program resources and materials.	Reduced automobile use avert private cost and time and reduces the negative impacts of pollution, congestion, and climate change. Increased walking and bicycling improve health and fitness and has a large favorable impact on health outcomes which reduces future healthcare costs. Extensive technical section with references provided for methods.	10 years	$8.0 mil	$27.9 mil	3.5:1	Fair
Sustrans 2014[32][b] Select projects, UK (3 projects)	No details. Likely the funded amount including any matching funds.	Averted healthcare cost from favorable long-term health outcomes due to increased walking and bicycling. Monetized value of reduced impacts on the environment due to reduced automobile use. Healthcare cost dominate most of the evaluations. Methods are consistent with guidance provided by the UK Department for Transport,[52] and the health benefits of walking and bicycling as modeled with WHO's Health Economic Assessment Tool (HEAT).[43]	30 years	Mean $664,865	Mean $5.21 mil	Mean 10.0:1 (All>1.0:1)	Fair
University of Toronto 2016[30] Toronto area, Canada (13)	Collected by facilitators from each school.	Benefits from reduced vehicle kilometers that reduce environmental and parent time impacts. Healthcare costs averted from health benefits of walking or bicycling. Based on methods from the Victoria Transport Policy Institute.[6]	5 years	$115,008	$724,017	6.3:1	Good

[a] Benefits for adults only.

[b] Computed by present reviewers.

B-C Ratio, benefit to cost ratio; CDC, Centers for Disease Control and Prevention; mil, million; SRTS, Safe Routes to School; ATS, active travel to school; UK, United Kingdom.1