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Final Report

Quantifying the Costs of School Transportation - Appendices I, II, & III

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Noreen McDonald , Ph.D., University of North Carolina at Chapel Hill
Ruth Steiner, Ph.D., University of Florida
Virginia Sisiopiku, Ph.D., TRIA Inc.
W. Mathew Palmer, MURP, University of North Carolina at Chapel Hill
Benjamin Lytle, MRP, University of Florida
Jeff Tsai, North Carolina State University
Thomas Cook, North Carolina State University

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DISCLAIMER

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AUTHORS

Noreen McDonald , Ph.D., University of North Carolina at Chapel Hill

Ruth Steiner, Ph.D., University of Florida

Virginia Sisiopiku, Ph.D., TRIA Inc.

W. Mathew Palmer, MURP, University of North Carolina at Chapel Hill

Benjamin Lytle, University of Florida

Jeff Tsai, North Carolina State University

Thomas Cook, North Carolina State University

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ABSTRACT

While there has been attention to the costs of school busing, there has been little analysis of the multi-modal costs of school transportation and how those costs vary with the local environment. This study identifies the individual capital and operations cost items for each primary mode of transportation—automobile, school bus, bike, and walking—to allow for the consistent collection of data between states and school districts. Nine public elementary schools were selected from Florida representing areas with high, medium and low densities of student populations. The same criteria were used to select 11 schools in North Carolina representing medium and low density environments. School districts, published reports, and professionals associated with the design and planning of the study schools were consulted to gather cost and other relevant information. A school site visit was conducted to determine the travel mode split at each study school. Based on these results, the researchers have documented cases that suggest that school travel modes and costs are related to built environment characteristics surrounding a school site – the greater pedestrian accessible residential density around a school site, the higher the rates of walking, bicycling and driving to school and the lower rates of bus ridership. Correspondingly, dense accessible school sites exhibit lower public costs.

EXECUTIVE SUMMARY

Background of Research
During the 2010-2011 school year, the U.S. public school transportation system supported the safe daily arrival and departure of over 49 million K-12 students. Budget estimates suggest that the cost associated with operating and maintaining this school travel system is $22 billion annually. However, estimates of school travel costs only include operating and maintenance expenses for school buses. Ignored are the physical infrastructure costs of providing access by buses and cars to the school, family costs for driving students to school, and external costs, such as safety and air quality. As a result, researchers and practitioners lack critical information needed to choose school locations and provide multi-modal access at reasonable cost.

Methods
To address the lack of knowledge on the multi-modal costs of school transportation, we developed a framework to understand and categorize the expenses for school bus, private vehicle, and pedestrian school travel and applied this framework to estimate transportation costs at twenty recently-constructed public elementary schools in North Carolina and Florida. Our analysis assessed school travel cost variations across different local built environment contexts using a mix of empirical observations and simulation-based approaches. Based on these analyses, we developed a practitioner tool - a school travel cost calculator -- that accounts for the comprehensive public, private, and external costs of school transportation across all modes.

Findings and Implications
This study finds that school travel mode rates and corresponding school travel costs vary with local built environment factors, such as pedestrian network connectivity and the number of residential units within a half mile of school. In respect to travel mode, bus ridership rates decrease and passenger vehicle and walking and bicycling to school rates increase as residential densities increase and pedestrian connectivity improves. Corresponding to these travel mode differences, less dense, pedestrian inaccessible school sites exhibited higher public capital and operational costs than more dense, pedestrian accessible school sites. However, while public capital and operational costs decreased with higher levels of residential density and pedestrian access, private and external costs increased with higher density and pedestrian connectivity. Increases in private and external costs are attributable to higher passenger vehicle rates for homes located near schools that are not eligible for public busing service. As a result, private costs of school travel are higher for more dense and accessible schools due to higher rates of passenger vehicle ridership. Lastly, sizeable travel mode and per student travel cost differences were observed for comparable schools in NC and FL; overall, private and external costs were higher in Florida due to higher rates of passenger vehicle ridership and active school travel.

These results suggest that the density of residences and pedestrian connectivity within a half mile of a school influence school travel modes and corresponding school travel costs; the further away the majority of students live, the higher the motorized school travel modes and costs of transporting students to school. In addition, state-level policy differences in NC and FL, such as minimum busing distance eligibility, influence school travel costs. Longer minimum busing distances redistribute the responsibility of school travel to families, as observed in Florida's higher private passenger vehicle and active school travel rates (compared to North Carolina).

Appendix I

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Development of a Cost Breakdown Structure for Quantifying School Transportation Costs for Various Modes

VIRGINIA P. SISIOPIKU, PHD[1]
University of Alabama at Birmingham, Associate Professor, Department of Civil, Construction & Environmental Engineering, 1075 13th St South, Hoehn 311,Birmingham, AL 35294, USA, Phone: 205-934-9912, Fax: 205-934-9855, Email: vsisiopi@uab.edu

OSSAMA RAMADAN, MS
University of Alabama at Birmingham, Graduate Research Assistant, Department of Civil, Construction& Environmental Engineering, 1075 13th St South, Hoehn 211,Birmingham, AL 35294, USA, Phone: 205-934-8430, Fax: 205-934-9855, Email: oramadan@uab.edu

NOREEN C. MCDONALD, PHD
University of North Carolina at Chapel Hill, Associate Professor, Department of City & Regional Planning, 317NewEastBldg,CB3140, ChapelHill,NC27599, USA, Phone: 919-962-4781, Fax:919-962-5206, Email: noreen@unc.edu

ABSTRACT
According to the US Department of Education, Americans spend over $20 billion annually to bus 25 million students to school. Yet, the state-of-practice clearly indicates that the direct and indirect cost of transporting children to school by alternate modes of transportation is not fully understood nor accounted for.
In a first ever attempt to address this issue, this paper offers a systematic documentation of capital, operation/ maintenance, safety, physical security and environmental costs of school transportation by mode. Modes considered include walking, biking, school bus, and private automobile. First, the paper proposes a cost breakdown structure. Then it identifies and summarizes related cost items. Following a comprehensive literature review, the probable ranges for the costs of school transportation by mode are documented. Detailed references are included to further assist researchers, planners, officials, and other potential users in measuring the multi-modal costs associated with school transportation and making informed decisions that optimize resource allocations.

KEYWORDS: School transportation costs; Walking, biking, school bus, automobile costs.

1. INTRODUCTION
In the United States, the federal government has delegated responsibility for school transportation policies to the state and local school districts. Review of current practices clearly indicates that such entities do not consider tradeoffs between land values and transportation costs as they make their decisions on siting new schools nor consider school transportation costs other than school busing for budgetary purposes. There

[1] Corresponding Author

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have been few attempts to systematically quantify the costs of school transportation and, more importantly, to link those costs to school and local government decisions about infrastructure. In fact, no studies can be identified that systematically investigate the infrastructure, operational, and safety related costs associated with getting students to school through a variety of transportation modes. Without such information in their disposal, decision makers are limited in their ability to make proper decisions on optimal selection of school siting and minimization of related school transportation costs.

To assess the full cost of school transportation, this paper proposes a methodology that considers the capital, operating, safety, and environmental expenses associated with school transportation using various modes (i.e., school bus, auto, walk, and bike). The paper establishes a cost breakdown structure, identifies related cost items, and summarizes probable ranges for the costs of school transportation by mode. The paper serves as a comprehensive, yet easy to follow reference guide for estimating school transportation costs for various transportation modes.

2. COST BREAKDOWN STRUCTURE

A large proportion of the school transportation costs that concern local districts, municipal governments, and state agencies is in the form of operating costs; however, the cost inventory has to account for those items of expenditure involved in establishing the selected school transportation system, while ensuring the system is safe, secure, and environmentally-friendly. Some of these expenditures may be one-time initial costs, or small items that occur frequently (or almost continuously), while others will be larger and may happen only in a few specific years over the system lifetime. In order to represent all these items of expenditure, a comprehensive framework should be used. This allows the full costs of alternative school transport options to be compared, thereby making explicit any trade-off between the initial capital outlay, maintenance, social, or environmental expenditures.

In Project Management, a hierarchical model in which a high-level task decomposes into a set of lower-level ones is known as Work Breakdown Structure (WBS) (Project Management Institute 2008). The same technique was used to propose a Cost Breakdown Structure for this study that was then used to decompose the various Cost Items of school transportation. The lowest level in the hierarchy was identified as a Cost Item. The Cost Breakdown Structure will provide a conceptual idea of this study size and scope (Government Accountability Office 2009).

The main types of transportation costs are Infrastructure Costs, Operating and Maintenance Costs, and Safety Costs. The National Association of State Directors of Pupil Transportation Services (2005) stated that the pupil transportation industry must account for school transportation security. Accordingly, such costs arising from securing school transportation should be also considered; therefore, a fourth type of costs (namely Physical Security Costs) was added. Also, Bickel et al. (2006) concluded that transportation infrastructure projects and the associated changes in transportation use lead to changes in the environmental burden and associated damages. They emphasized that the environment impact is an important element to consider when assessing the costs and benefits of transport infrastructure projects. Accordingly, a fifth Cost Item was identified, which is Environmental Impacts.

As shown in Figure 1, the Cost Breakdown Structure as discussed hereinafter shall decompose those five types of costs into a hierarchy of Cost Items, and then probable ranges shall be assigned to each item.

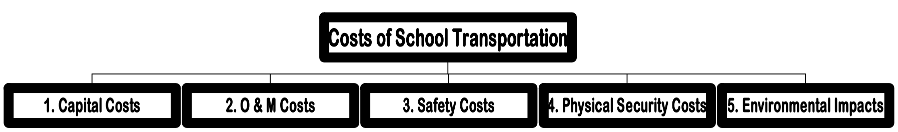

Figure 1: First Hierarchical Level of Cost Breakdown Structure

2.1 Capital Costs

Capital Costs are costs associated with acquiring the necessary infrastructure for the proposed mode of school transportation. The recognized modes of school transportation are walking, biking, school bus, private car, and public transit. Due to the complexity and lack of ridership count for school transportation by means of public transit, this study focuses on four modes of school transportation, namely: walking, biking, school bus, and private car. The necessary infrastructure by mode can be identified by investigating (from a local district or school perspective) what infrastructure the student will use on his/her way to school as follows:

- ***Walking:*** The student who opts to walk to school will use the sidewalk, crosswalks, and traffic control signal devices.
- ***Biking:*** Students who opt to bike to school will use bike lanes, crosswalks, and traffic control signal devices. At the school site, they will use bike racks or corrals to park their bikes.
- ***School Bus:*** Students who will use the school bus, will use the vehicle (school bus), roadway, traffic control signal devices, drop-off and pick-up lanes, and eventually the school bus will have to be parked at some parking facility.
- ***Private Car:*** Students who will commute to school by private cars will use the roadway, traffic control signal devices, drop-off and pick-up lanes, and on-site parking.

The used infrastructure, related facilities, and vehicles involved in pupil transportation to school have associated costs that are paid by local districts, municipal governments, and state agencies. The decomposition of capital costs is into three main cost groups, namely: (i) highway construction / lane addition costs; (ii) parking and facility costs; and (iii) vehicle acquisition costs.

More specifically, highway construction / lane addition costs could be allocated in USD per linear feet per lane constructed, and could be further decomposed into three cost items, namely:

1. ***Right-of-way acquisition:*** This cost item accounts for the value of the land needed for the scheme (and any associated properties), compensation payment necessary under state and federal laws, and the related transactions and/or legal costs. In case of existing right-of-way, this item should account for the *Opportunity Costs* for the existing right-of-way.
2. ***Construction of the road / lane***: This cost item accounts for materials, labor, energy, preparation, professional fees, and disruption costs that are necessary for building a new road or adding a lane. This applies to traffic lanes, bike lanes, and sidewalks.
3. ***Signals and other control equipment***. This cost item accounts for labor, material and equipment costs for installation of signals at intersections or midblock locations, with pedestrian pushbuttons, LED, masts, and school flashing systems.

Also, Parking and Facility Costs could be allocated in USD per square feet of constructed facility, and may be further decomposed into three cost items according to the type of facility, namely parking lot construction, drop-off / pick-up lanes, bike racks / corrals and transportation center related costs.

Table 1 summarizes the various capital costs related to school transportation by type of mode.

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Table 1: Capital Costs of School Transportation by Mode

Cost Group/Item paid by local districts, municipal governments, and state agencies		Unit	Transportation Mode			
Code	**Description**		**Walking**	**Biking**	**School Bus**	**Private Car**
1	**Capital Costs**					
1.1	Highway Construction / Lane addition	ft.				
1.1.1	Right-of-way acquisition Including the value of the land needed for the scheme (and any associated properties), compensation payment necessary under state and federal laws, and the related transactions and/or legal costs. In case of existing right-of-way, this item should account for the *Opportunity Costs* for the existing right-of-way.		✓	✓	✓	✓
1.1.2	Construction of the road / lane Including materials, labor, energy, preparation, professional fees, and disruption costs.		✓	✓	✓	✓
1.1.2.1	Traffic Lanes				✓	✓
1.1.2.2	Bike Lanes			✓		
1.1.2.3	Side Walks		✓			
1.1.3	Installation of signals and other control equipment		✓	✓	✓	✓
1.2	Parking and Facility					
1.2.1	Parking Lot Construction	Sq. ft.			✓	✓
1.2.2	Drop-Off/Pick-Up Lanes	Sq. ft.				✓
1.2.3	Bike Racks / Corrals	Ea.		✓		
1.2.4	School Bus Transportation Center (inclusive of bus garage bays, fueling infrastructure, administrative offices, remote satellite maintenance facilities, purchase of fuel trucks that deliver fuels to staging locations, and service trucks that travel to staging location for service calls.)	Bus			✓	
1.3	Vehicle Acquisition	Ea.			✓	

Table 2 lists the itemized Capital Costs of school transportation including their RS Means Line Number (RSMLN), were applicable, as stipulated by Montgomery MPO (2012) and Reed Construction Data (2011a, b). The states of Florida (FL) and North Carolina were selected as case study states for demonstration purposes and costs were adjusted using appropriate location factors from Reed Construction Data (2011b)for those states as illustrated in Table 2.

Table 2: Capital Costs for School Transportation

Cost Group/Item paid by local districts, municipal governments, and state agencies		**Unit**	**Cost (adjust by state)**	
Code	**Description**		**FL**	**NC**
1	**Capital Costs**			
1.1	Highway Construction / Lane addition			
1.1.1	Right-of-way acquisition *[Including the value of the land needed for the scheme (and any associated properties), compensation payment necessary under state and federal laws, and the related transactions and/or legal costs. In case of existing right-of-way, this item should account for the Opportunity Costs for the existing right-of-way.]*	Sq. ft.	Vary	Vary
1.1.2	Construction of the road / lane Including materials, labor, energy, preparation, professional fees, and disruption costs.			
1.1.2.1	Traffic Lanes			
1.1.2.1a	Roadway, bituminous concrete paving, 2½″ thick, 24′ wide. Including all materials, labor, and equipment. *[In 2011 USD, RSMLN G2010-210-1520]*	L.F.	114	101
1.1.2.1b	New Construction Extra Cost for Additional Lane on Urban Arterial*[2012 USD as reported by Florida Department of Transportation (2012, 2)]*	L.F.	315	279
1.1.2.2	Bike Lanes			
1.1.2.2a	Shared Roadway *[Montgomery Metropolitan Planning Organization (2012, F-7) reported $5.39 for Birmingham, AL in 2012 USD. Figure was adjusted for location using RS Means location adjustment factors]*	L.F.	5.34	4.72
1.1.2.2b	Bicycle lane *[Montgomery Metropolitan Planning Organization (2012, F-7) reported $112 for Montgomery, AL in 2012 USD. Figure was adjusted for location using RS Means location adjustment factors]*	L.F.	123	109

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Cost Group/Item paid by local districts, municipal governments, and state agencies		**Unit**	**Cost (adjust by state)**	
Code	**Description**		**FL**	**NC**
1.1.2.2c	Shared-Use Path *[Montgomery Metropolitan Planning Organization (2012, F-7) reported $257 for Columbus, GA in 2011 USD. Figure was adjusted for location using RS Means location adjustment factors]*	L.F.	281	249
1.1.2.3	Sidewalks			
1.1.2.3a	Bituminous sidewalk, 1″ thick paving, 4′ gravel base, 3′ width. [In *2011 USD, RSMLN G2030-110-1580*]	L.F.	6	4
1.1.2.3b	Concrete sidewalk, 4′ thick, 4′ gravel base, 3′ width. *[In 2011 USD, RSMLN G2030-120-1580]*	L.F.	15	13
1.1.3	Installation of signals and other control equipment.			
1.1.3a	Mid block pedestrian crosswalk with pushbutton and mast arms. *[In 2011 USD, RSMLN 34-41-13.10-0020]*	Total	95,693	84,643
1.1.3b	Traffic signals, school flashing system, solar powered, remote controlled. *[In 2011 USD, RSMLN 34-41-13.10-0600]*	Signal	23,122	20,452
1.1.3c	Intersection traffic signals, LED, mast, programmable, no lane control. Includes all labor, material, and equipment for complete installation. *[In 2011 USD, RSMLN 34-41-13.10-1010]*	Signal	194,850	172,350
1.1.3d	Intersection traffic signals, LED, mast, programmable, R/L lane control. Includes all labor, material, and equipment for complete installation. *[In 2011 USD, RSMLN 34-41-13.10-1110]*	Signal	254,171	224,821
1.1.3e	Add protective/permissive left turns to existing traffic light. Includes all labor, material, and equipment for complete installation. *[In 2011 USD, RSMLN 34-41-13.10-1210]*	Signal	80,538	71,238
1.1.3f	Re-allocation of Street Lighting	L.F.	Vary	Vary
1.2	Parking and Facility			
1.2.1	Parking Lot Construction Inclusive of all structures and priced per car.			

Cost Group/Item paid by local districts, municipal governments, and state agencies		**Unit**	**Cost (adjust by state)**	
Code	**Description**		**FL**	**NC**
1.2.1a	Parking lot, 90° angle parking, 3′ bituminous paving, 6′ gravel base. *[In 2011 USD, RSMLN G2020-210-1500]*	car	1,035	915
1.2.1b	Parking lot, 60° angle parking, 3′ bituminous paving, 6′ gravel base. *[In 2011 USD, RSMLN G2020-210-1800]*	car	1,035	915
1.2.1c	Parking lot, 45° angle parking, 3′ bituminous paving, 6′ gravel base. *[In 2011 USD, RSMLN G2020-210-2200]*	car	1,061	938
1.2.2	Drop-Off/Pick-Up Lanes			
1.2.3	Bike Racks / Corrals Galvanized Bike Racks, 18-bike capacity *[In 2012 USD as listed on http://www.ParkItBikeRacks.com]*	Ea.	170~490	
1.2.4	School Bus Transportation Center			
1.2.4a	Building and one bus bay *[In 2010 USD as reported by Kay et al. (2011, 19)]*	L.S.	400,000~800,000	
1.2.4b	Additional bus bay *[In 2010 USD as reported by Kay et al. (2011, 19)]*	Bus	300,000~500,000	
1.2.4c	Additional bus outdoor storage *[In 2010 USD as reported by Kay et al. (2011, 19)]*	Bus	5,000~10,000	
1.2.4d	Fueling Infrastructure *[In 2010 USD as reported by Kay et al. (2011, 18)]*	L.S.	85,000~110,000	
1.3	Vehicle Acquisition *[In 2010 USD as listed by Kay et al. (2011, 3) for school bus with 40 – 54 student capacity (no standees) and a service life of 10 – 12 years or 350,000 – 500, 000 miles.]*	Ea.	110,000~200,000	

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Table 2: Operations and Maintenance Costs of School Transportation by Mode

Cost Group/Item paid by local districts, municipal governments, and state agencies		Unit	Transportation Mode			
Code	**Description**		**Walking**	**Biking**	**School Bus**	**Private Car**
2	**O&M Costs**					
2.1	Operating Costs	annual				
2.1.1	Operating Labor		✓		✓	
2.1.2	Fuel				✓	
2.1.3	Depreciation and interest on capital				✓	
2.1.4	Insurance and licensure fees				✓	
2.2	Maintenance Costs					
2.2.1	Infrastructure Routine Maintenance		✓	✓	✓	✓
2.2.1.1	Roadway (including street marking, potholes, and patches)					
2.2.1.2	Control devices					
2.2.1.3	Vegetation control					
2.2.1.4	Trash cleanup					
2.2.1.5	Snow removal					
2.2.2	Vehicle Routine Maintenance	VMT			✓	
2.2.2.1	Parts					
2.2.2.2	Labor					
2.2.2.3	Fluids and Lubricants					
2.3	Overheads	L.S.			✓	

2.2. Operation and Maintenance Costs

Operation and maintenance costs account for such costs necessary to operate and/or maintain the usefulness of the corresponding school transportation mode. Such costs also include associated overheads that may be incurred by local districts, municipal governments, and state agencies in connection with school transportation operations. Operation and maintenance costs could be decomposed into three main cost categories, namely: (i) operation costs; (ii) maintenance costs; and (iii) overheads.

Operation Costs include all costs associated with school transportation operations in such manner to provide the service up to Federal and State standards. Mostly these costs relate to school transportation by buses; hence, it should be allocated in terms of USD per annum. The relevant cost items are:

1. ***Operating Labor:*** This cost item accounts for salaries, wages, and benefits paid by local districts, municipal governments, and state agencies to operate the school transportation system. Paid personnel would include bus drivers, parking/facility attendants, security officers, in-house mechanics and service men, and administrative personnel in connection with school transportation operations.
2. ***Fuel:*** This cost item accounts for fuel costs associated with school bus operation.

3. ***Depreciation and interest on capital:*** This cost item accounts for interest on capital costs and depreciation costs of school transportation investments.
4. ***Insurance and licensure fees:*** This cost item accounts for all insurance and licensure provided by local districts, municipal governments, and state agencies such as vehicle licensure, vehicle insurance, or liability insurance.

Maintenance Costs include all costs that should be paid by local districts, municipal governments, and state agencies to assure that the school transportation system is operational and functional up to the Federal and State standards. These costs could be further divided into two cost sub-categories as follows:

- ***Infrastructure Routine Maintenance:*** This cost sub-category includes all costs necessary to keep the infrastructure in good working condition for all users. Such are pertinent to roads, bike lanes, sidewalks, parking lots, and drop-off/pick-up lanes. These costs are recurrent in nature and therefore should be allocated in USD per annum. The relevant cost items are:
    - *Roadway Maintenance Costs*: These are costs incurred due to maintaining the roadway to attain certain levels of service. These costs include resurfacing, street marking, fixing potholes and patches.
    - *Control Devices Maintenance Costs:* Associated costs include replacing traffic light bulbs, repairing control devices, repairing wiring, and replacing faded or broken signs.
    - *Vegetation Control Costs:* This cost item accounts for such operations that control sidewalk and/or shoulder vegetation to insure safe and aesthetic operation of the roadway, sidewalk, or bike lane as appropriate.
    - *Trash Cleanup Costs:* This cost item accounts for all costs related to removing or handling road trash.
    - *Snow Removal Costs:* This cost item is applicable to roadways that suffer from snowfall during the snow season. Snow removal is very important for the safety of vehicles and pedestrians.
- ***Vehicle Routine Maintenance Costs:*** This cost sub-category accounts for all costs incurred by local districts, municipal governments, and state agencies to maintain the fully safe and functional operational status of school buses. Such costs are recurring in nature and could be allocated in USD per either *Vehicle Miles Travelled* (VMT) or annum.
    - *Parts:* Cost item accounts for replacing school bus parts whether the replacement was planned or due to part failure.
    - *Labor:* This cost accounts for wages paid incidentally to labor associated with vehicle maintenance; however, such cost could be implicitly paid within other cost items.
    - *Fluids and Lubricants:* This cost item accounts for fluids and lubricants changed regularly within the vehicle routine maintenance scheme.

The third cost category within Operation and Maintenance Costs is Overheads, which includes all costs that are associated with school bus operations but cannot be directly allocated as Operation Costs or Maintenance Costs. Overheads are payable by State, local district, or school in association with school buses as follows:

- ***Traffic congestion costs***: FHWA (1997) identified traffic congestion costs as such costs that represent and/or account for:
    - Added travel time for persons and commercial movements.
    - Speed-related effects on fuel use and other components of motor vehicle operating costs.
    - Increased variability of travel time.
    - Increased driver stress associated with operating a motor vehicle under stop-and-go conditions.
- ***Traffic services costs*** include costs associated with operating traffic signals, street lightings, street maintenance, parking, ambulance services, and police services.

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Table 3 summarizes the various operation and maintenance costs by type of mode.

Table 3: Operating and Maintenance Costs of School Transportation

Cost Group/Item paid by local districts, municipal governments, and state agencies		**Unit**	**Cost**
Code	**Description**		
2	**O&M Costs**		
2.1	Operating Costs		
2.1.1	Operating Labor		
2.1.1a	Bus Driver		
2.1.1b	Crossing Guards *[In 2011 USD as reported by Bureau of Labor Statistics (2011b)]*	Annual	24,080
2.1.2	Fuel *[In 2011 USD as reported by Michigan School Business Officials (2011) based on 3 year average consumption and diesel price of $3.19 per gallon (03/29/2011 #2 Diesel ULS).]*	Bus/year	5,454.90
2.1.3	Depreciation and interest on capital *[Average amount for all types of vehicles as reported by AAA (2011) in 2011 USD]*	Annual	4,948.80
2.1.4	Insurance and licensure fees *[Average amount for all types of vehicles as reported by AAA (2011) in 2011 USD]*	Annual	1,684.80
2.2	Maintenance Costs		
2.2.1	Infrastructure Routine Maintenance *[In 2012 USD for Sacramento, CA as reported by Sacramento Area Council of Governoments (2012, 1)]*	Mile/year	15,000
2.2.1.1	Roadway (including street marking, potholes, and patches)	included	
2.2.1.2	Control devices	included	
2.2.1.3	Vegetation control	included	
2.2.1.4	Trash cleanup	included	
2.2.1.5	Snow removal	included	
2.2.2	Vehicle Routine Maintenance *[All inclusive figure in 2011 USD based on 3 year average as reported by Michigan School Business Officials (2011)]*	Annual	14,529
2.2.2.1	Parts	included	
2.2.2.2	Labor	included	
2.2.2.3	Fluids and Lubricants	included	
2.3	Overheads		

Cost Group/Item paid by local districts, municipal governments, and state agencies		**Unit**	**Cost**
Code	**Description**		
2.3a	Traffic Congestion Costs *[As extracted from Table V-23 by FHWA (1997) in 2000 USD]*	VMT	0.0338~0.3759
2.3b	Traffic services costs *[As extracted from Table 5.8.7-1 by Litman and Doherty (2009, 5.8-5) in 2007 USD]*	VMT	0.013~0.020

South Carolina Legislative Audit Council (2001, 1) estimated the State operating expenditures for student transportation to be USD 350 per student in 1999 USD.

Table 4 lists in more detail the Operations and Maintenance costs of school transportation as estimated by AAA (2011), Litman and Doherty (2009), FHWA (1997), and Michigan School Business Officials (2011).

Table 4: Safety Costs of School Transportation by Mode

Cost Group/Item paid by local districts, municipal governments, and state agencies		**Unit**	**Transportation Mode**			
Code	**Description**		**Walking**	**Biking**	**School Bus**	**Private Car**
3	**Safety Costs**	**Annual**				
3.1	Fatalities		✓	✓	✓	✓
3.2	Injuries		✓	✓	✓	✓
3.3	Property Damage				✓	✓

2.3. Safety Costs

Safety Costs are costs associated with fatalities, injuries, or property damages. The National Safety Council (2007) defines an *Injury* as bodily harm to a person, *Fatality* as any death resulting from a fatal injury, and *Property Damage* as harm to property that reduces the monetary value of that property. Mohan (2002) identified costs associated with fatalities, injuries, or property damage as follows:

1. ***Medical Costs*** including emergency medical services, hospitalization, rehabilitation, mental health, and related treatment costs, as well as funeral and/or coroner expenses for fatalities and administrative costs of processing medical payments to providers.
2. ***Administrative Costs*** including police, fire, and/or legal and court costs.
3. ***Property Damage Costs*** including costs of incident clearing services, repairs, and/or loss in property value.
4. ***Work Loss Costs*** account for productivity losses. These costs include personnel's lost production in terms of equivalent wages, as well as school productivity losses caused by temporary or permanent worker absence.

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Table 5summarizes the various safety costs associated to school transportation by type of mode and Table 6 illustrates National Safety Costs in 2010 USD as stipulated and classified by Highway Safety Manual, First Edition cited by Herbel, Laing, and McGovern (2010, 4-5).

Table 5: Safety Costs by Type

Cost Group/Item paid by local districts, municipal governments, and state agencies		**Unit**	**Cost**
Code	**Description**		
3	**Safety Costs**		
3.1	Fatalities	EA	4,008,900
3.2	Injuries		
3.2a	Disabling Injury	EA	216,000
3.2b	Evident Injury	EA	79,000
3.2c	Fatal Injury	EA	158,200
3.2d	Possible Injury	EA	44,900
3.3	Property Damage	EA	7,400

Table 6: Physical Security Costs of School Transportation by Mode

Cost Group/Item paid by local districts, municipal governments, and state agencies		**Unit**	**Transportation Mode**			
Code	**Description**		**Walking**	**Biking**	**School Bus**	**Private Car**
4	**Physical Security Costs**	**Annual**				
4.1	Detection and Surveillance Costs			✓	✓	✓
4.2	Response Costs		✓	✓	✓	✓

2.4 Physical Security Costs

DeAngelis, Brent, and Ianni (2011)investigated the hidden costs of school security, and they identified Texas as one of the few, if not the only, state that requires its districts to use a dedicated code to report security expenditures. They stated that the Texas Education Code defined security activities as "activities to keep student and staff surroundings safe, whether in transit to or from school, on a campus or participating in school-sponsored events at another location." They further grouped such costs into two main groups, which are *Detection and Surveillance Costs*, and *Response Costs*. These groups need no further decomposition; therefore, they will be used as Cost Items.

Detection and Surveillance Costs include costs resulting from installation and operation of surveillance systems at parking lots and facilities; were vehicles, bikes, and school buses may be prone to theft and/or vandalism. These costs would apply to all modes except walking. The other Cost Item is *Represents Costs*, which include costs associated with dispatched security officers to handle security incidents and after-hours or early morning escorts to walking students. This Cost Item applies to all school transportation modes.

Table 7 summarizes physical security costs by type of mode. Detection and surveillance costs vary considerably and estimates of such costs are not practical without considering the specific needs of a school site. Security response costs and cost for providing security at school sites vary according to the responsibilities, qualifications, and hours of employment of the security personnel. The 2011 national estimate provided by the Bureau of Labor Statistics (2011a) for mean hourly wage of security guards that patrol, or monitor premises is USD 13 or 27,040 annually. For North Carolina the reported annual mean wage of security personnel at elementary and secondary schools is USD 25,960 (in 2011 USD) and for Florida it is USD 23,310.

Table 7: Environmental Costs of School Transportation by Mode

Cost Group/Item paid by local districts, municipal governments, and state agencies		Unit	Transportation Mode			
Code	**Description**		**Walking**	**Biking**	**School Bus**	**Private Car**
5	**Environmental Impacts**					
5.1	Air quality	ton			✓	✓
5.2	Noise	cap/yr			✓	✓
5.3	Global Warming	GWP			✓	✓

2.5 Environmental Impacts

According to Bickel et al. (2006), transportation projects and the associated changes in transport-use lead to changes in the environmental impact and associated damages. They recommended that environmental damages should be avoided or compensated as far as possible, e.g. loss of habitats due to constructing a road, water quality etc. Usually, this is ensured by following the requirements of the Environmental Protection Agency (EPA) for carrying out an Environmental Impact Assessment, or by obligations to meet certain target values (e.g. for noise levels) or thresholds (e.g. for airborne pollutants). However, even if such standards are met, the remaining impacts lead to environmental costs, which have to be considered when evaluating alternatives. Their general recommendation was – wherever possible – to value impacts, not environmental burden. Accordingly, the *Environmental Costs* that should be considered in this study are solely associated with school bus and private car transportation operations as follows:

1. ***Air Pollution:*** The valuation of air pollution effects should be based on the damages caused by air pollutant emissions. The types of impacts for which dose-response relationships are established are human health impacts, agricultural and forestry production losses, as well as soiling and corrosion of building materials. The recommended quantification method is using cost factors in USD per ton of pollutant emitted.
2. ***Noise:*** Since this project is concerned with costs that are payable by schools, districts, or states, the *Environmental Cost* due to *Noise* shall be limited to health impacts related to the long term exposure to noise, mainly stress related health effects like hypertension and myocardial infarction. Such costs could be calculated by relating such impacts to noise exposure per year per person exposed.
3. ***Global Warming:***Bickel et al. (2006) recommended the method described by Watson, Zinyowera, and Moss (1997) for calculating costs due to the emission of greenhouse gases (usually expressed as CO_2 equivalents). This method simply quantifies such costs by multiplying the amount of CO_2 equivalents

emitted by a cost factor (usually established by EPA or State authorities). The CO_2 equivalent of a greenhouse gas is derived by multiplying the amount of the gas by the associated Global Warming Potential (GWP). The GWP for methane is 23, for nitrous oxide 296, and unit GWP for CO_2.

Table 8 summarizes environmental costs of pupil transportation to school by type of mode and Table 9 lists ranges for Environmental Impacts of school transportation. Litman and Doherty (2009) estimated the air pollution costs of diesel buses and average cars that are attributable to non-greenhouse gases, and greenhouse gases. Noise costs were estimated by FHWA (1997) as the loss in residential property value associated with exposure to various noise levels at specified distances from the roadway using FHWA noise models.

Table 8: Environmental Impacts of School Transportation

Cost Group/Item paid by local districts, municipal governments, and state agencies		**Unit**	**Cost**	
Code	**Description**		**Car**	**Bus**
5	**Environmental Impacts**			
5.1	Air quality			
5.1a	Non-GHG Air Pollution Costs *[In 2007 USD as extracted from Table 5.10.7-1 by Litman and Doherty (2009, 5.10-27)]*	VMT	0.004~0.062	0.013~0.185
5.1b	Greenhouse Gas Damage Costs *[In 2007 USD as extracted from Table 5.10.7-3 by Litman and Doherty (2009, 5.10-27)]*	VMT	0.132~0.161	0.660~0.806

3. CONCLUSION

Bridging a gap in available literature, this study is the first that documented in a systematic way the full cost of transporting children to school using various transportation options. As such it is a valuable reference resource for planners wishing to estimate up-front and on-going transport costs associated with proposed school locations and for school administrators and other decision makers.

This study identifiedin great detail costs related to transportation of pupils to school with various modes (i.e., walking, biking, school bus, or private automobile). The paper proposed a cost breakdown structure, identified related cost items, and summarized probable ranges for the costs of school transportation by mode. The studybenefitsmultipleconstituenciesby providingthefirstpublishedevidenceregardingthe fullcostof schooltransportation--acrossallmodesandincludingup-frontandon-goingcosts.

In future work, the information in this paperwill support the development of a decision support tool capable of estimating multi-modal transportation costs to potential school sites. Currently, no such tool is available, thus hindering the ability ofschooldistrictsandmunicipalitiesto make properly informed decisions on wheretosite new schools for optimizing overall school transportationcosts.

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Appendix II

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Assessing multimodal school travel safety in North Carolina

Noreen C. McDonald[a,*], Ann B. McGrane[a,b], Eric A. Rodgman[a], Ruth L. Steiner[c], W. Mathew Palmer[a], Benjamin F. Lytle[c,d]

[a] University of North Carolina at Chapel Hill, USA
[b] Port Authority of New York and New Jersey, USA
[c] University of Florida, USA
[d] AECOM, Orlando, Florida, USA

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ABSTRACT

School transportation has been the subject of numerous federal and state policies since the early twentieth century–the Safe Routes to School program is the most recent example. However, few recent studies have thoroughly analyzed the risks and costs associated with different modes of transportation to school. Our descriptive study assessed the injury and fatality rates and related safety costs of different modes of school transportation using crash and exposure data from North Carolina, USA from 2005 to 2012. We found that riding with a teen driver is the most dangerous mode on a per trip basis with injury rates 20 times higher and fatality rates 90 times higher than school buses, which had the lowest injury rates. Non-motorized modes had per trip injury rates equivalent to school buses but per trip fatality rates were 15 times higher than for school buses. The economic costs of school travel-related injuries and fatalities for walking, biking, and teen drivers were substantially higher than other modes. This research has important policy implications because it quantified the risks of different school travel modes which allows policymakers to consider how safety investments can reduce risks. Decades of effort by schools, communities, and the government have made school buses a very safe mode and endeavored to reduce risks to teen drivers. This study highlighted the need for these same actors to reduce the risks of injury for walking and bicycling. As more improvements are made to infrastructure around schools, repeated studies of this type will allow practitioners to examine whether the improvements help mitigate the risks.

1. Introduction

While safe access to school is considered a basic right in much of the world, developed countries have evolved vastly different systems for providing this access. Japan, for example, locates schools so that nearly all children in the country can walk or bicycle (Schoppa, 2012). Similarly many northern European countries rely heavily on walking and biking with supplements from transit and autos. For example, nearly 50% of German 5–14 year olds walked or bicycled in 2008, 20% were driven, and the remainder used transit or other modes (McDonald, 2012). For historical reasons, North America has developed a very different school transport system with nearly one-third of students using school-provided transport–generally yellow school buses (Buliung et al., 2009; McDonald et al., 2011). The extensive use of specialized vehicles operated for the exclusive use of schoolchildren is a unique feature of the North American system and one linked to the lower density environment and pivotal societal shifts such as rural school consolidation and, in America, school desegregation.

American efforts to ensure safe school travel have focused on improving the safety of school buses (McCray and Brewer, 2000). Other countries, because there were no exclusive school modes, focused more broadly on maintaining a safe urban environment for walking, bicycling, and public transit. More recently, the US federal government has supported efforts to encourage active transportation by increasing the safety of walking and bicycling to school through the Safe Routes to School program (FHWA, 2008). Despite the increased importance of multi-modal school transport in the American context, few studies have looked comprehensively at school travel safety across modes. More than a decade ago, the Transportation Research Board (TRB) addressed this issue by analyzing school travel related crashes and found that biking and, then, walking had the highest injury and fatality rates after accounting for distance traveled (National Research Council, 2002). School buses and transit buses had the lowest rates of injury and

* Corresponding author. 317 New East Building, CB 3140, Chapel Hill, NC 27599-3140, USA. Tel.: +1 919 962 4781.
E-mail address: noreen@unc.edu (N.C. McDonald).

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Table 1
US school travel injury and fatality rates.
Source: National Research Council (2002).

	Annual injuries		Annual fatalities	
	Per 100 million trips	Per 100 million kilometers	Per 100 million trips	Per 100 million kilometers
School bus	100	10	0.3	<0.1
Passenger vehicle-adult driver	490	60	1.6	0.2
Passenger vehicle-teen driver	2300	270	13.2	1.5
Bicycling	1610	1280	9.6	7.6
Walking	310	370	4.6	5.4
Other bus	120	10	0.1	<0.1

Note: Based on US crash data from 1991 to 1999.

fatality. The risk of injury or death in a passenger vehicle was dependent on whether the driver of the vehicle was a teenager or an adult, as passenger vehicles with a teenage driver had more than 4.5 times the risk of those with an adult driver (National Research Council, 2002).

The goal of this paper is to update TRB's work from 2002 by conducting a descriptive analysis to estimate injury and fatality rates using data from 2005 to 2012 and to advance earlier research by estimating the monetary costs associated with injuries and fatalities related to school travel. While the TRB study was nationwide, our analysis focused on North Carolina, USA because the state has high-quality crash data for all modes and injuries to students entering and exiting school buses have been an important policy issue in the state (Bridges, 2012; Phillips, 2012; Trenda, 2013). The North Carolina legislature recently passed a law imposing harsher penalties on drivers who pass a stopped school bus. As of December 2013, drivers can have their licenses revoked for 30 or more days for passing a stopped school bus, and drivers who hit a pedestrian while passing a stopped school bus are charged with a felony (Hanes and Lambeth, 2013).

2. Background

Until recently, concern with school travel safety in the United States was synonymous with school bus safety. The National Traffic and Motor Vehicle Safety Act of 1966 and subsequent School Bus Safety Amendments in 1974 permitted the US Department of Transportation (US DOT) to define minimum standards for new school buses sold within the United States (Committee on Injury, Violence, and Poison Prevention and Council on School Health, 2007). Research on school bus safety has focused on how engineering improvements could improve outcomes for vehicle occupants (National Transportation Safety Board, 1999). For example, analysis showed that buses designed with "strong, closely spaced seats" provided improved safety (McCray and Brewer, 2000). After 1977, the government required all school bus manufacturers to use this compartmentalization design.

Research on the safety of child pedestrians began in the mid-1970s (Reiss, 1975). Many studies have analyzed spatial and demographic patterns of child pedestrian injury, the ability of children to safely navigate the city, and the impacts of safety education programs (Appleyard, 1981; Malek et al., 1990; Mendoza et al., 2012; Schwebel et al., 2008; Southworth, 1990). Safe Routes to School programs emerged in Denmark in the 1970s to improve the safety of non-motorized travel (National Center for Safe Routes to School, 2013). These programs moved globally with the National Center for SRTS documenting programs in Europe, Australia, and New Zealand (National Center for Safe Routes to School, 2013). In the late 1990s, the US National Highway Traffic Safety Administration funded two pilot Safe Routes to School (SRTS) programs (National Center for Safe Routes to School, 2013). The federal SRTS program, established in 2005 under the Safe Accountable Flexible Efficient Transportation Equity Act: A Legacy for Users (SAFETEA-LU), solidified the importance of non-motorized school travel by providing funds to states for use in improving infrastructure and providing education related to pedestrian and bicycle school travel (FHWA, 2008).

While there have been numerous studies of safety for individual modes, there have been relatively few efforts to evaluate the risks of school travel across modes. The 2002 TRB report on The Relative Risks of School Travel provided the most complete picture by estimating exposure-adjusted injury and fatality rates for the United States. As shown in Table 1, the analysis highlighted elevated rates of injuries and fatalities for teen drivers, walkers, and bicyclists (National Research Council, 2002). School buses and other buses were found to provide the lowest rate of injuries and fatalities per trip and per mile.

A similar, less comprehensive study from New Zealand concurred with the injuries per trip findings from the TRB, determining that biking and walking were the riskiest modes of travel to school based on exposure, followed by private automobiles and then buses (Schofield et al., 2008). The study was limited, however, because it only examined crashes over a two-year period and mode choice information was determined using a survey that only asked about morning travel to school. Another study in Iowa, USA examined school bus injuries and fatalities per 100 million miles using crash data from the 2002 to 2005 school years. It found that the risk of injury per 100 million miles driven was 13.6, while the risk of fatality per 100 million miles was 0.4 (Yang et al., 2009). However, this study is not directly comparable to the previously mentioned studies because it used bus miles traveled rather than passenger miles traveled. Other studies have focused on all travel instead of just school-related travel to determine overall relative risk by mode. An analysis of the United States found that bicyclists and pedestrians were 2.3 and 1.5 times more likely, respectively, than occupants of a passenger vehicle to be fatally injured on a per-

Table 2
Fraction of value of statistical life based on injury severity.
Source: Rogoff and Thomson (2014).

AIS Level	Severity	Fraction of VSL	Cost (2013$)
1	Minor	0.003	$28,000
2	Moderate	0.047	$433,000
3	Serious	0.105	$968,000
4	Severe	0.266	$2,453,000
5	Critical	0.593	$
6	Unsurvivable	1.000	$9,220,000

Table 3
Injury severity conversions.

Crash data injury level	Associated AIS level	Relative weight AIS	Economic cost (2013$)
K	6	1.00	$9,220,000
A	5	0.050	$1,355,000
	4	0.12	
	3	0.83	
B	2	1.00	$433,000
C	1	1.00	$28,000

trip basis (Beck et al., 2007). Consistent with other studies, this analysis also found that bus travel was the safest mode of transportation. A UK road safety study assessed fatalities per time traveled and found similar fatality rates across modes, e.g. driving, walking, and bicycling (Mindell et al., 2012). Using time as opposed to distance or trips provided a very different evaluation of risk. Unfortunately the study did not use a direct measure of time spent traveling but imputed time based on average travel speeds in the UK and National Travel Survey estimates of distance-traveled.

3. Methods

The goal of our research was to estimate exposure-adjusted injury and fatality rates and safety costs by school travel mode for North Carolina. We utilized the approach for calculating school travel safety risks used in The Relative Risks of School Travel report, which determined risk metrics for each mode of travel to school by combining crash data on injuries and fatalities with travel surveys that provided exposure estimates. The difficulty is that while travel surveys distinguish trip purpose, crash data does not. In practice, this meant that school-related travel had to be identified by the time of the crash rather than by a definitive indicator of the trip purpose (National Research Council, 2002). After calculating annual injury and fatality rates by mode, we used estimates of the value of statistical life to estimate the economic costs of injuries and fatalities related to school travel.

3.1. Study area

We chose North Carolina as the study area because it has high-quality crash records and recent concerns about school travel safety have been part of the state's political debate. North Carolina has a combination of urban, suburban, and rural environments that mostly favor automobile travel. The average statewide density is approximately 200 persons per square mile, while the metropolitan regions, such as Charlotte-Gastonia-Salisbury and Raleigh-Durham-Cary, have densities around 400 persons per square mile, respectively (U.S. Census Bureau, 2010).

According to the North Carolina Department of Public Instruction, approximately 1.6 million students were enrolled in public and private schools (not including home-schooled children) in the state during the 2011–2012 school year (North Carolina Department of Public Instruction, 2012). North Carolina experienced rapid growth in the last decade, with a 15% increase in school-age populations from 2000 to 2010 (National Center for Education Statistics, 2010). This growth in school-age population reinforced the need to analyze the risks and costs of school travel so that parents and policymakers can make educated decisions about school travel choices.

3.2. Injuries and fatalities

We determined child injuries and fatalities that occurred during school travel periods by analyzing police crash reports compiled by the Highway Safety Research Center at the University of North Carolina at Chapel Hill. We analyzed data from 2005 to 2012 and reported the annual average. Because trip purpose was not indicated in the crash report form, we identified times of day and year when the majority of school travel would take place and used it as a proxy for school-related travel. These dates and times were derived from researchers' knowledge of school calendars and typical bell schedules. For the purposes of this study, school travel-related crashes were defined as crashes that involved a person aged 5 to 18 and occurred:

- From August 26 to December 20 or January 1 to June 9 and
- On a weekday (Monday–Friday) between 6:00–8:59 AM or 2:00–4:59 PM.

Injuries and fatalities involving children during school travel periods were grouped by travel mode: school bus, passenger vehicle and motorcycle, pedestrian, bicycle, and other bus. For passenger vehicles and motorcycles, we distinguished teen versus adult drivers due to previous research which has documented sharply differing injury and fatality rates between these two groups. Passenger vehicles included cars, vans, sport utility vehicles, pickup trucks, other trucks, recreational vehicles, and taxis. We grouped motorcycle and passenger vehicle crashes. While it would be preferable to distinguish them, there were a very limited number of motorcycle incidents in North Carolina that involved children and, most critically, our exposure data did not show any motorcycle use. For school bus crashes, we included pedestrians in a school bus-related crash as school bus-related crashes. This approach followed the methodology of The Relative Risks of School Travel report, which assumed that child pedestrians involved in a school-bus related crash were likely to have been

Table 4
Population estimates for the number of trips and kilometers traveled during school hours in North Carolina, 2009.

	Trips (million)			Kilometers (million)			Average trip length (km)	
	Est.	95% CI	(%)	Est.	95% CI	(%)	Est.	95% CI
School bus	285	(248, 321)	34	2960	(2360, 3561)	33	10.4	(8.7, 12.1)
Passenger vehicle-adult driver	337	(309, 366)	40	3768	(3046, 4490)	42	11.2	(9.6, 12.8)
Passenger vehicle-teen driver	124	(103, 145)	15	1647	(1186, 2109)	19	13.3	(10.3, 16.3)
Bicycle	8	(4, 12)	1	8	(4, 12)	0	1.0	(0.7, 1.3)
Pedestrian	62	(39, 86)	7	65	(36, 94)	1	1.0	(0.7, 1.4)
Other bus	27	(5, 49)	3	440	(37, 842)	5	16.4	(8.8, 24.1)
Total	843	(787, 900)	100	8888	(7793, 9984)	100	10.5	(9.5, 11.6)

Table 5
Annual exposure-adjusted injury and fatality rates by mode for school travel in North Carolina.

	Frequency			Per 100 million trips		Per 100 million kilometers	
	N	95% CI	(%)	Est.	95% CI	Est.	95% CI
Injuries							
School bus	505	(462, 551)	6	178	(152, 205)	17	(10, 26)
Passenger vehicle-adult driver	2721	(2619, 2825)	31	806	(752, 863)	72	(57, 90)
Passenger vehicle-teen driver	5230	(5089, 5373)	60	4215	(4089, 4343)	317	(283, 353)
Bicycle	35	(24, 48)	0	425	(386, 467)	434	(394, 476)
Walk	120	(99, 143)	1	192	(165, 220)	184	(158, 211)
Other bus	47	(35, 63)	1	175	(150, 202)	11	(5, 18)
–							
Total injuries	8657	(8476, 8841)	100	1026	(965, 1090)	97	(79, 118)
–							
Fatalities							
School Bus	1.1	(0, 5.6)	2	0.4	(0, 2.2)	0.0	(0, 0.4)
Passenger vehicle-adult driver	9.7	(4.5, 17.7)	16	2.9	(0.6, 7)	0.3	(0, 1.7)
Passenger vehicle-teen driver	44.8	(32.4, 59.6)	76	36.1	(25.3, 48.8)	2.7	(0.5, 6.8)
Bicycle	0.5	(0, 4.7)	1	6.2	(2.3, 11.9)	6.3	(2.4, 12.1)
Walk	3.0	(0.4, 8.0)	5	4.8	(1.5, 10.0)	4.6	(1.4, 9.7)
Other bus	0.0	(0.0, 3.0)	0				
–							
Total fatalities	59.1	(44.9, 76.1)	100	7.0	(2.8, 13.1)	0.7	(0, 2.9)

Based on crashes that occurred between 2005 and 2012 during school travel periods and involved 5–18 year olds in North Carolina.

riders of the school bus and should therefore be included in the school bus mode. The pedestrian mode included injuries sustained by walkers as well as the small number of injuries sustained by children traveling on skateboards, roller skates, and scooters.

A small proportion of records, less than one percent of crashes, had an unknown injury or fatality type. We distributed the unknown injuries among the fatalities and injury levels based on the relative prevalence of those types of fatalities or injuries within the crash category. The 95% confidence interval for annual counts of injuries and fatalities were estimated exactly using formulas available in Fay and Feuer (1997, p. 792).

3.3. Exposure

We used the 2009 National Household Travel Survey (NHTS) to calculate the number of student trips and miles traveled in North Carolina during school travel hours in aggregate and by mode. Data on trips and miles traveled were used to calculate exposure-adjusted rates of injury and fatality during school travel periods. For travel in passenger vehicles, we distinguished teen (defined as 18 or younger) from adult drivers. The NHTS North Carolina sample contained data on 1475 children between the ages of 5 and 18 who made 3417 trips during school travel periods. Population estimates and variances were computed using the US DOT provided replicate weights in Stata 12 (College Station, TX).

We imputed missing information on trip distance, travel mode, and driver age. Trip distance was imputed by assigning the modal average trip distance to records with missing data ($n = 71$). Travel mode was imputed by stochastically selecting a travel mode based on the relative modal distribution for records without missing information ($n = 21$). Driver age was missing for all trips where a non-household member drove the passenger vehicle due to the design of the NHTS survey ($n = 81$). Missing information on driver age was imputed by age cohort because younger children were more likely to travel with adults. We determined the relative distribution of passenger vehicle trips with adult and teen drivers among youth with no missing information and then used this relative distribution to stochastically assign records with missing data as teen versus adult driver. Specifically, we found that children 10 and under drove exclusively with adult drivers; for 11–14 year olds 93% of auto trips were with adult drivers; for 15–16 year olds, 59% of auto trips were with adults; and for 17 and 18 year olds, 11% of auto trips were with adult drivers.

Exposure-adjusted rates of injuries and fatalities were computed by dividing the annual injury and fatality counts by mode by the population estimates of modal trips and kilometers. The 95% confidence interval for these rates was computed using the gamma distribution with a scale parameter equal to one and a shape parameter equal to the observed rate (Beck et al., 2007; Fay and Feuer, 1997).

3.4. Economic costs of injuries and fatalities

We used guidance on the value of statistical life from the US DOT to estimate the economic costs associated with injuries and fatalities related to school travel. The US DOT reported the value of a statistical life was $9.2 million in 2013 dollars (Rogoff and Thomson, 2014). For our study, the value of a statistical life equated to the economic costs associated with a fatality. To estimate the costs of injuries, we utilized the DOT guidance which linked injury

Table 6
Annual school-travel related injury and fatality costs in North Carolina (2013$).

	Injuries				Fatalities		
	Annual (millions)	Per injury	Per trip	Per km	Annual (millions)	Per trip	Per km
School bus	$36.0	$77,900	$0.13	$0.01	$10.2	$0.04	$0.00
Passenger vehicle-adult driver	$302.7	$134,700	$0.90	$0.08	$89.6	$0.27	$0.02
Passenger vehicle-teen driver	$790.3	$203,000	$6.37	$0.48	$412.7	$3.33	$0.25
Bicycle	$11.3	$776,900	$1.37	$1.40	$4.7	$0.57	$0.58
Walk	$36.2	$641,900	$0.58	$0.56	$27.6	$0.44	$0.42
Other bus	$2.1	$46,400	$0.08	$0.00	$0.0	$0.00	$0.00
–							
Total	$1,178.6	$175,400	$1.40	$0.13	$544.9	$0.65	$0.06

Based on crashes that occurred between 2005 and 2012 during school travel periods involving children between 5 and 18.

severity to costs (Table 2). Injury severity was measured on the Abbreviated Injury Scale (AIS) 2005 Update 2008. The AIS is a standardized scale to assess crash victims and is generally assigned by medical personnel as opposed to police officers at the crash site. The scale ranges from 6 ("unsurvivable") to 1 ("minor"). We estimated the economic cost of each injury type by multiplying the US DOT-suggested fraction of the value of statistical life (VSL) by the VSL, as shown in Table 2. For example, a critical injury would be $9.2 million multiplied by 0.593 or approximately $5.5 million.

While the economic costs of injuries were estimated by US DOT using the AIS scale, our crash data reported injury severity using the KABCO scale commonly used by police departments through the United States (Council et al., 2005). In the KABCO scale, K represents fatalities, level A injuries are considered incapacitating; level B injuries are non-incapacitating with evident injuries; and level C injuries include possible injuries such as momentary unconsciousness or limping (National Research Council, 2002). To estimate costs on the KABCO scale, we coded the AIS levels to the KABCO scale. Fatalities were directly linked with AIS 6. For injuries, we grouped AIS 3 through 5 as A injuries, AIS 2 as B injuries, and AIS 1 as C injuries. We felt that AIS 3, which is described as including a major nerve laceration, a multiple rib fracture, or a hand, foot, or arm amputation, was a serious enough injury level to be considered an A injury on the KABCO scale (Sinha and Labi, 2011). We calculated the economic cost of A injuries as the weighted average of the cost of AIS 3 to 5. The weights were based on the relative distribution of these injuries in national data from 1993 to 1996. Specifically, AIS 5 comprised 5% of A injuries, AIS 4 represented 12%, and AIS 3 was 83% (Mackay and Hassan, 2000). The result, as shown in Table 3, is that level A injuries cost approximately $1.355 million per injury, level B injuries cost $433,000 per injury, and level C injuries cost $28,000 per injury. To calculate the annual economic costs of injuries and fatalities during the school travel period in North Carolina, we multiplied the cost per injury in Table 3 by the number of annual incidents by the KABCO scale. We also presented the costs per trip and per kilometer to account for the relative prevalence of each mode.

4. Results

4.1. Amount of school travel

The 2009 NHTS recorded 843 million trips during school travel periods in North Carolina, which equated to 468 annual school trips per person with 196 annual trips per person to school and 272 from school in the state. The higher number of trips in the afternoon travel period is likely explained by more complicated trip chains after school and the inclusion of trips to non-school afternoon activities. As seen in Table 4, the most common mode during school travel periods was a passenger vehicle driven by an adult, followed by the school bus. A higher percentage of North Carolina student trips traveled in a passenger vehicle driven by a teenager than by walking and biking combined. Walking and biking trips averaged one kilometer, while motorized trips averaged over ten kilometers.

4.2. Injuries and fatalities

As shown in Table 5, over 90% of annual injuries and fatalities occurred to students traveling in passenger vehicles. Six percent of injuries and 2% of fatalities involved school buses. Walking and bicycling accounted for less than 2% of annual injuries and 6% of annual fatalities. Teen drivers had substantially higher injury and fatality rates per trip than all other modes. On a per kilometer basis, injury and fatality rates for passenger vehicles driven by teens, pedestrians, and bicyclists were substantially higher than school buses and passenger vehicles driven by adults.

We assessed the contributing factors surrounding school bus-related pedestrian injuries and fatalities due to recent policy interest in decreasing these incidents. Of the 77 pedestrian-school bus injuries and fatalities recorded from 2005 to 2012, 57% of the crashes involved a school bus hitting a pedestrian. The remaining 43% of the crashes were attributed to a driver of a passenger vehicle passing a stopped school bus. For those injuries and fatalities that involved a school bus hitting a pedestrian, the most cited driver contributing factor was driver inattention.

4.3. Economic costs of injuries and fatalities

Table 6 shows the economic costs of injuries and fatalities to 5–18 year olds during school travel periods. Aggregate and per-trip costs for teen drivers are substantially higher than other modes. On a per-kilometer basis, injury and fatality costs are high for teen drivers, bicyclists, and pedestrians. School buses had very low safety costs reflecting the high usage and low injury rates for this mode. Bicyclists and pedestrians had the highest cost per injury of the modes, because non-motorized modes of travel had a higher proportion of severe injuries. For example, approximately 17% of bicyclist crashes resulted in an A-level injury, while only 4% of teen driver crashes resulted in an A-level injury.

5. Discussion

This study assessed injury and fatality rates as well as safety costs of traveling to school in North Carolina. Compared to the nationwide risk metrics reported in The Relative Risks of School Travel, North Carolina had higher numbers of injuries and fatalities per 100 million trips and 100 million kilometers for passenger vehicles and school buses. Non-motorized modes, however, had lower or equivalent rates of injury and fatality than the nation. Given the difference in time periods between the two studies, it is not clear if North Carolina has different accident patterns than the United States or if patterns have shifted in the time between the two studies.

Teen drivers have very high injury and fatality rates, even on a per mile basis. North Carolina, along with other states, has attempted to address this issue through a graduated licensing process that limits the time a young driver may drive while unsupervised or the number of passengers under 21 that can be in the car. Strong licensing programs have been associated with decreases in fatal crashes for 16 year olds (Master et al., 2011). However, the continued high levels of injuries and fatalities among teen drivers highlight the ongoing challenges of addressing this issue.

Buses (school bus and other bus) provided the safest travel to school for children likely reflecting the very substantial investments made by the public sector in ensuring safety for this mode. School bus-related travel could become even safer if fewer drivers of passenger vehicles illegally pass stopped school buses and if school bus drivers continue to monitor for child pedestrians entering or exiting the bus. The recently passed North Carolina law that more harshly punishes those who pass stopped school buses makes it important to re-examine the results of this study in a few years to see if the law has had a measurable impact on the safety of children traveling to school in North Carolina (Trenda, 2013). Other approaches include policies on school bus stop placement to minimize the need for students to cross busy roads.

In North Carolina, walking and bicycling had lower injury rates per trip than passenger vehicles, but injuries to non-motorized travelers were more severe. Per trip rates of fatality for walking and bicycling were equivalent to passenger vehicles. Programs such as

Safe Routes to School have highlighted the need to systematically make walking and bicycling safer for children and recent studies have proven the effectiveness of the program in decreasing injuries and increasing walking and bicycling (DiMaggio and Li, 2013; McDonald et al., 2014; Ragland et al., 2014). North Carolina received an allocation of $31million from the federal government through the SRTS program for 2005 to 2012 or approximately $3.9 million annually (National Partnership for Safe Routes to School, 2014). Our analysis estimated the annual economic costs of injuries and fatalities to walkers and bicyclists to equal almost $80 million annually. These figures suggest the need for sustained attention, and perhaps more resources, to the topic of non-motorized school travel safety.

The limitations to this study result from the sources for crash and exposure data. Crash databases are based on police reports, which means that non-fatal or non-serious injuries, especially those involving pedestrians and bicyclists, are likely underreported (Agran et al., 1990). While North Carolina state law requires incidents on public roads involving motor vehicles to have a crash report, the law does not require completion of a NC DMV-349 crash report for pedestrian or bicycle incidents that do not involve a motor vehicle (Division of Motor Vehicles, Traffic Records Branch, 2012). Therefore, pedestrian and bicycle injuries that do not involve some type of motor vehicle are not included in the crash statistics. Another issue with the data is that exposure data does not take into account road types or other aspects of the built environment. The relative risk of travel by bike or by walking could be dramatically different in an area with good pedestrian and bicycle infrastructure than it is in a conventional, auto-oriented post-WWII suburban environment. Finally, the international context for school travel differs substantially with many countries have higher rates of walking and bicycling and lower rates of teen driving and school buses.

6. Conclusions

Many of our study's results corroborate the results of the 2002 TRB report, The Relative Risks of School Travel. Namely, school bus transportation has a very low relative risk of injury or fatality compared to other modes of transportation used to travel to school and teen drivers have the highest injury and fatality rates. Walking and bicycling have lower injury rates than driving with an adult, but higher fatality rates. Our study provides a more nuanced view of school transportation by adding cost estimates on a per-trip and per-mile basis. With these cost estimates, we can account for differences in injury severity that occur based on the mode of travel chosen. What we find is that walkingand biking injuries are more costly because they are often more severe. Rather than using this information to discourage people from walking or biking, we hope it provides the impetus to improve the built environment as it relates to pedestrians and bicyclists. Our documented low risk of travel by school bus provides an example of how decades of focus on safety for a particular mode can lead to excellent results.

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Appendix III

Transportation
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Costs of school transportation: quantifying the fiscal impacts of encouraging walking and bicycling for school travel

Noreen C. McDonald · Ruth L. Steiner · W. Mathew Palmer · Allison N. Bullock · Virginia P. Sisiopiku · Benjamin F. Lytle

Abstract National governments have provided subsidies for investments in increasing the safety and attractiveness of walking and biking to school. Evaluations of Safe Routes to School initiatives have found that they have been effective at changing behavior and reducing injuries. However, there has been little attention to the impacts of these programs on pupil transportation costs. This analysis assesses the potential economic benefits of Safe Routes to School programs in the US context by estimating the annual costs of using motorized transport for short trips to schools, examining real-world examples of the costs savings of SRTS programs, and evaluating land use impacts on school transportation costs using a simulation analysis of school bus routes. We find that there is potential for school districts and families to reduce transport expenditures through public sector investments in walking and biking infrastructure near schools. We also find that land use context matters

N. C. McDonald (✉) · W. M. Palmer
Department of City and Regional Planning, University of North Carolina, New East Building, CB 3140, Chapel Hill, NC, USA
e-mail: noreen@unc.edu

W. M. Palmer
e-mail: wmpalmer@email.unc.edu

R. L. Steiner · B. F. Lytle
Department of Urban and Regional Planning, University of Florida, Gainesville, FL, USA
e-mail: rsteiner@dcp.ufl.edu

B. F. Lytle
e-mail: ben.lytle@aecom.com

A. N. Bullock
Alta Planning + Design, Durham, NC, USA
e-mail: bullock.allison@gmail.com

V. P. Sisiopiku
Department of Civil, Construction, and Environmental Engineering, University of Alabama at Birmingham, Birmingham, AL, USA
e-mail: vsisiopi@uab.edu

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and the most cost-effective investments would benefit schools where large numbers of children live within walking distance.

Keywords School transport · Safe routes to school · Costs · School bus · Hazard busing

Introduction

Numerous studies have documented the positive economic impacts of investments in walking and bicycling infrastructure due to the health benefits of increased physical activity, improved safety, and decreased air pollution (Cavill et al. 2008; Jarrett et al. 2012). While these benefits have been studied across the population, there has been particular interest in the impacts on children and adolescents. In recent decades, levels of physical activity have decreased and obesity has increased among this group (Ogden et al. 2014). One policy response has been the introduction of Safe Routes to School (SRTS) programs that aim to increase walking and bicycling to school by making routes to school safer, providing education, and conducting encouragement programs. Currently such initiatives are found in Europe, New Zealand, Australia, Canada, and the United States. Researchers have looked at the impacts of these programs and found they lead to increased active travel and physical activity, and decreased injuries (DiMaggio and Li 2013; Stewart et al. 2014; Ragland et al. 2014; McDonald et al. 2014; Larouche et al. 2014).

Missing from the literature on the benefits of SRTS programs has been consideration of how these programs impact the public and private costs of getting students to and from school. This is a particularly important issue in the North American context where the public sector provides specialized school transport. American schools spent $22.3 billion on student transportation expenses (or 4.2 % of all education spending) during the 2010–2011 school year (U.S. Department of Education, National Center for Education Statistics 2013). However, the topic is also relevant outside North America where students often rely on public transit for school transport, a system which operates with public sector support. And across all countries, parents provide a substantial portion of school transport often by driving students to school.

This study uses mixed methods to assess the fiscal impacts of encouraging walking and bicycling for school travel. The focus is on understanding how improving pedestrian and bicycle infrastructure near schools could reduce the use of cars and buses for short trips to school. Reducing motorized transport could decrease public sector costs for busing students to school, private sector costs to families that drive their children to school, and related external costs of congestion and air quality. We assess these impacts through examination of real-world examples and a simulation analysis of school bus routing. The discussion assesses the spatial contexts where SRTS programs could generate the largest economic benefits and how economic benefits to districts and families relate to the costs of pedestrian and bicycle infrastructure.

This analysis is timely because recent cuts in education spending have disproportionately fallen on support services, such as transportation, in order to preserve classroom funding. Pupil transportation departments across the country have faced decreased budgets and increased fuel costs. This combination has led many districts to cut school bus service, potentially jeopardizing access to education for students. While this article focuses on the US context, these questions are transnational. Facing similar challenges, the UK and Australian governments are considering cutting subsidies for school travel (van Ristell et al. 2014; Cook 2012; Anonymous 2012). The current model of using motorized transport to overcome hazardous walking conditions may no longer be sustainable in the US or globally. This article highlights how SRTS can play a role in developing a new multi-modal model of pupil transportation that promotes walking and biking for short trips and preserves school bus or public transit service for longer trips.

School transportation costs background

Getting children to school requires large expenditures by the public sector on school bus operations and infrastructure. But school transportation costs are not exclusively public. Nearly half of American students use private vehicles to reach school (McDonald et al. 2011). These families bear financial costs in terms of vehicle operation and time. Beyond the direct costs borne by public and private actors, school travel also imposes costs on society through externalities like vehicle emissions and congestion. These costs are justified by the enormous benefits to individuals and society of ensuring access to education for all children.

The remainder of this section provides an overview of public, private, and external school transportation costs in aggregate and for school trips of 1 mile or less. We highlight trips of 1 mile or less because walking and bicycling are viable modal substitutes for motorized transportation at these distances. National travel survey data show that fewer than 35 % of students living within a mile from school walk or bike in the United States; the remainder of students use private automobiles (44 %) or ride the school bus (19 %) [authors' calculations using the 2009 National Household Travel Survey (Federal Highway Administration 2011)]. SRTS programs aim to change these travel patterns through education, encouragement, enforcement, and engineering strategies that make active modes safer and more attractive.

Public sector

In 2010–2011, student transportation expenses amounted to $22.3 billion dollars in personnel and fuel costs U.S. Department of Education, National Center for Education Statistics (2013). The share of education expenditures for student transportation varied by state, from 2.4 % in California to 7.3 % in West Virginia. Transportation costs per enrolled student also varied widely across states. In Utah, the per-student cost of transportation was just $197, well below the national average of $452 (U.S. Department of Education, National Center for Education Statistics 2013). Other states with below average transportation costs per student included California ($220), Texas ($245), Oklahoma ($243), and Colorado ($250). Conversely, some states had high per pupil transportation costs far exceeding the national average. The District of Columbia had the highest per pupil cost in the nation at $1,404 per student per year. New York ($982), New Jersey ($834), West Virginia ($879), and Connecticut ($803) also have higher than average per pupil transportation expenses.

However, state-level average per pupil transportation costs are not a strong metric of cost-effectiveness due to the variation in transportation policies and child density across states and school districts. Some of the observed cost differentials are caused by differing state rules around pupil transportation. California and Texas, for example, do not have state legislation that requires student busing (McDonald and Howlett 2007). New York not only requires transportation for students (for kindergarten through eighth grade students living more than 2 miles from school, and for ninth through twelfth grade students living more than 3 miles from school), but also reimburses a large proportion of those costs. Some states, such as California, have lower average costs simply because they are transporting a smaller proportion of students. Conversely, rural states and school districts may transport children longer distances because of the dispersed nature of population settlement, which increases costs. In addition, some pupil transportation costs are mandated by the federal government and cannot be voluntarily reduced by school districts. Busing is federally required for all homeless students and students with documented special needs. While national data on special needs busing is scarce, a 2002 study by the Center for Special Education Finance estimates that special needs busing costs account for 28 % of total pupil transportation expenditures nationwide (Chambers et al. 2002).

Hazard busing

Most districts provide school bus service when students live more than a specified minimum distance from school, generally 1–2 miles. However, many districts bus children to school if the walking conditions are unsafe even when they do not meet the distance threshold; this is known as “hazard busing.” According to Chriqui et al. (2012), just under a third of states allow exemptions to the minimum distance requirements when hazardous walking conditions exist and other states allow informal exemptions. Little is known about hazard busing rates nationwide, but the provision of busing for short distances creates policy challenges. In 2009, American families reported that 5.6 % of elementary and middle school students lived within 1 mile of school and used a school bus (authors’ calculations using the 2009 National Household Travel Survey). Presumably, a large portion of these students received hazard busing, though that was not asked in the survey. Florida provides detailed annual estimates of hazard busing. In the 2011–2012 school year, 1 % of all students in Florida received hazard busing; this equated to 4 % of all students riding the bus (Florida Department of Education 2013). However, there is great variation across school districts. In Hillsborough County, which includes Tampa, 6 % of all students are bused due to hazardous walking conditions. In Escambia County, which includes Pensacola, 12 % of students receive hazard busing (Florida Department of Education 2013).

Estimating the costs of providing school bus service to students living within a walkable distance of their school is difficult given uncertainties in prevalence. However, the available US data suggest that approximately one to five percent of students receive hazard busing. This equates to 0.5–2.5 million American students who receive hazard busing. Per student costs for hazard busing are likely less than the US average per-student transportation cost of $452 because that figure includes students with special needs and those that live quite far from school. If we assume that hazard busing costs are substantially less because of the short distances involved (approximately $200 per student) then the annual cost of hazard busing is between $100 and $500 million across the United States.

Private costs

Over half of American students reach school by private vehicle (McDonald et al. 2011). Parents drive children for many reasons including convenience, time savings, concerns about traffic safety and stranger danger, or a lack of other options if the school does not provide busing (McDonald and Aalborg 2009; Dellinger and Staunton 2002; Zhu and Lee 2009). In high school, many teens drive themselves and, in some cases, classmates to school. McDonald et al. (2011) found that auto trips to and from school accounted for 30 billion vehicle miles and 6.6 billion vehicle trips in 2009. Of these trips, 40 % were undertaken specifically to drop a child at school and then return home (McDonald et al. 2011). The American Automobile Association (AAA) estimates the cost of gas, maintenance, and tires at 20 cents per mile (American Automobile Association 2013). Based on these estimates, auto trips to and from school cost a minimum of $2 billion if we only consider cases where parents made a special trip or a maximum of $6 billion if we consider all private vehicle school mileage.

The estimates above ignore the value of travelers' time. We know of no research that has investigated the value of parents' time while chauffeuring children to school. There is anecdotal evidence that some parents place positive value on driving children to and from school because of the opportunity to spend time with their children; for others, it may impose costs because of decreased time available for paid employment. The US Department of Transportation provides general guidance on the value of travel time and suggests that time spent traveling should be valued at 35–60 % of after-tax hourly wages ($8.40–$14.40) for local, personal travel (Trottenberg 2011). Using the low end (35 %) of the Department of Transportation range and assuming travel speeds average 30 mph, we found that the time costs of parents' driving children to school are around $3 billion for special trips to drop children at school and $8 billion for all school-related mileage.

Private vehicle costs of short school trips

In 2009, 44 % of the 10 million elementary and middle school students living within 1 mile of school were driven to school (National Center for Education Statistics 2012; Federal Highway Administration 2014). We estimate that the costs to the private sector of these short-distance trips were approximately $720 million or 4.5 % of the estimated aggregate costs of driving children to school. These costs reflect the vehicle operating expenses and value of parent travel time for short trips where a parent made a special trip to bring their child to school. While many parents drop children on their way to work, approximately 40 % make special trips to bring children to school (McDonald et al. 2011). Assuming an average one-way trip distance of a half-mile for these students and vehicle occupancy of 1.5 children, we estimate that driving K-8 students living within 1 mile of school generates 1.5 billion *excess* vehicle miles of travel annually. Assuming vehicle operation costs of 20 cents per mile (American Automobile Association 2013), this equates to $300 million in private vehicle expenses. If we include the value of time in these estimates, the costs of parents driving children to school increase substantially. If those 1.5 billion excess vehicle miles represent approximately 50 million excess hours of travel (assuming a rather fast average travel speed of 30 mph), then the collective value of the travel time is $420 million when the value of time is 35 % of the average hourly wage rate.

External costs

Travel generates other costs which are not necessarily borne by the public or private sectors. These externalities include the adverse health impacts of vehicle emissions, the climate impacts of greenhouse gas emissions, and the time costs imposed on other road users due to congestion. Schools have been identified as major trip generators (McMillan 2007). During the school year, up to 25 % of morning traffic on local roads and 5–7 % of vehicle miles traveled are generated by parents driving their children to school (McDonald et al. 2011; Parisi Associates n.d.). According to the Federal Highway Administration, estimates of the monetary costs of congestion delays range from $0.01 to $0.09 per vehicle mile traveled. For local air pollution damage, the cost estimates for an average car range from $0.01 to $0.07 per vehicle mile traveled and from $0.01 to $0.21 per vehicle mile traveled by diesel bus. For greenhouse gas control and damage costs, the estimates for an average car range from $0.02 to $0.21 per vehicle mile traveled and from $0.84 to $1.03 per vehicle mile traveled by diesel bus (Litman and Doherty 2009; Federal Highway Administration 1997). Considering vehicle mile traveled (VMT) only related to special purpose school trips, this would cost approximately $120 million for congestion, $120 million for air pollution, and $240 million for greenhouse gas impacts.

External costs for trips of 1 mile or less

Above we estimated that driving children to school a distance of less than 1 mile generated 1.5 billion excess private vehicle miles of travel annually. Using the low end of the cost range for these externalities, we find that driving children to school for short trips generates at least $15 million in congestion costs, $15 million in air pollution costs, and $30 million in greenhouse gas costs annually. We are unable to estimate costs associated with excess school bus trips because we lack information about how hazard busing affects school bus VMT nationally.

Summary

In total, annual expenditures on school transportation operating expenses for motorized modes are approximately $30 billion for school districts and families (Table 1). We estimate that the proportion of those expenses related to transporting students short distances (defined as less than 1 mile) are approximately $0.9 to $1.3 billion or 3–5 % of total public and private sector costs. Externalities from private vehicle school trips, such as traffic congestion near schools and the air quality impacts of additional driving, add to this cost, though those expenses are difficult to estimate.

Impacts of safe routes to school programs on school transportation costs: methodology

We used mixed methods to assess the economic impacts of SRTS. First, we documented real-world examples of SRTS improvements leading to cost savings for school districts and families. To identify these examples, we reviewed the literature and contacted each state's designated Safe Routes to School State Coordinator and technical assistance staff from the Safe Routes to School National Partnership. Of the 51 state coordinators contacted, 21 (42 %) responded. A small number of respondents provided examples of SRTS investments that had resulted in reduced school bus or private vehicle costs. For each of the identified examples, we reached out to local contacts and conducted open-ended interviews through email or phone to gather information about the impacts of SRTS on busing and driving to school. From this process, we identified four case studies in Highland Park, NJ; Columbia, MO; Phoenix, AZ; and Austin, TX. The literature also contained examples from Auburn, WA; Marin County, CA; Eugene, OR; and Wooster, OH. Our examination focused on the connections between SRTS improvements and public and private sector costs; we did not focus on the factors that led to successful implementation of the SRTS program since other publications have addressed this topic (see for example National Center for SRTS 2012).

Table 1 Summary of the costs associated with motorized school transportation: all trips and trips less than 1 mile

	Total costs—all distances ($ million)	Costs—trips ≤ 1 mile ($ million)
Public sector		
School districts	22,300	100–500
Private sector		
Private vehicle operating costs	2,000–6,000[a]	300
Value of parents' travel time	3,000–8,000[a]	420
Externalities		
Traffic congestion near schools from autos	120–300[a]	15
Traffic congestion near schools from school buses	Not estimated	Not estimated
Air pollution and greenhouse gases from Autos	360–900[a]	45
Air pollution and greenhouse gases from school buses	Not estimated	Not estimated

[a] The low end considers only trips made solely to chauffeur a child to school; the high end considers all school-related VMT including trips where parents dropped children on their way to another destination

Second, we used simulation analysis to estimate how busing children short distances impacted the overall efficiency and costs of school bus service and to understand how these impacts varied with local context, particularly child density and average distance between home and school. For example, a SRTS program at a school where all students lived within walking distance could come close to eliminating motorized transport costs. Conversely, SRTS improvements would not decrease busing costs if no students lived within walking and biking distance of the school. We then assessed the savings in school bus costs that would result from getting students who lived near school to walk and bike. These costs savings were then compared to the costs of SRTS improvements.

We utilized school bus routing software to simulate the potential impacts of SRTS programs on busing costs. As a case study, we selected four elementary schools from a large North Carolina public school district for the analysis; magnet schools were excluded. The schools were selected to ensure variation in the number of students living near school. School A with 92 % of students living within 1 mile was located in an urban part of the district (Table 2). School D, where only 22 % of students lived within 1 mile of the school, was located in a suburban/exurban area, where the development patterns were characterized by loop- and lollipop-type residential subdivisions. The remainder of the schools varied between those two extremes.

To estimate how a SRTS program could impact busing costs by reducing the need for hazard busing, we analyzed three scenarios for each school (Table 3). These scenarios varied in the proportion of students living near the school that were bused. Under scenario 1 (no hazard busing), no students living within 1 mile of the school were assigned to bus routes. For scenario 2, we assumed that half the students living within 1 mile of school received hazard busing; students were selected at random. The final scenario assumed that all students living within 1 mile of school required hazard busing. For each of the three scenarios, students living outside walking distance, i.e. 1 mile, were included in the analysis, but their assignment (bus/no bus) never changed and was based on what the students had elected. For each scenario and school, the Pupil Transportation Group at North Carolina State University used Education Logistics (EDULOG) software to calculate school bus vehicle miles traveled (VMT), the number of buses used, and the number of students

Table 2 Characteristics of schools in simulation analysis

	Students living within 1 mile (%)	# of students	Average travel distance to school (miles)	Development pattern near school
School A	92	385	0.8	Gridded streets
School B	74	604	0.8	Gridded streets
School C	62	264	1.4	Gridded streets
School D	22	460	2.5	Loop and lollipop

Table 3 School busing simulation scenarios

Student residence	Scenario 1 no hazard busing	Scenario 2 half hazard busing	Scenario 3 all hazard busing
Within 1 mile of school	None bused	50 % of students bused (selected at random)	100 % of students bused
More than 1 mile from school	Current ridership status	Current ridership status	Current ridership status

serviced. For input parameters, such as maximum trip length, arrival times, and bus stop locations, we utilized state or district standards. We did not attempt to estimate how changes in hazard busing would impact private sector costs.

The estimates of bus route VMT and number of buses were then used to estimate the costs to the school district to provide school bus service of each scenario. The two components of variable school district transport costs are capital expenditures (the money required to purchase buses) and operations and maintenance. We assumed the district utilized a two-tiered school transport structure where one bus can service two schools in the morning and afternoon due to staggered bell times. In practice, this means that capital and operating expenses associated with the school bus are divided by two to account for the fact that one school bus serves two routes. For capital costs, we estimated annual costs per school bus by amortizing the school bus purchase costs of $86,500 over an anticipated 20 year lifespan at a social discount rate of 3.5 % (Delucchi 2005, pp. 3–4; Moore et al. 2004). Based on these calculations, we estimated that each additional bus route required $3,043 annually in capital costs (i.e. half of the amortized cost per school bus) (Table 4). Annual expenses for operating and maintaining the school transportation network include $0.49 per daily school bus vehicle mile for fuel, $7.42 in insurance costs per student bused, and $14,216 per school bus route for vehicle maintenance, driver and mechanic pay, and safety monitoring (Table 4). These costs were derived from an investigation of school transportation costs in North Carolina and reported values from the literature (Sisiopiku et al. 2013).

Results

The following sections present the results of our mixed-methods investigations of the potential for non-infrastructure investments to reduce school transportation costs, particularly to the public sector. The first section documents real-world examples of school

Table 4 Estimated public sector costs of providing school bus service

	Per school bus route[a]	Per daily bus VMT	Per student bused
Annualized school bus capital costs	3,043	0	0
Operating costs			
Insurance	0	0	7.42
Fuel	0	0.49	0
Bus driver	6,813	0	0
Vehicle maintenance	7,265	0	0
Detection and surveillance (including GPS)	138	0	0
Total operating expenses	14,216	0.49	7.42
Total capital + operating	17,259	0.49	7.42

[a] Assumes two-tiered bus routes

districts that reduced costs to the school district and families through SRTS programs. The second section reports on the school bus routing simulation analysis that assessed whether reductions in hazard busing could reduce school district transportation expenses.

Results: real-world examples of the economic impacts of SRTS investments

Through interviews with SRTS experts and the literature, we identified five examples where investments in SRTS reduced busing costs and three examples of reduced private vehicle costs.

Public costs: reduced school busing service

Starting in fall 2008, the Highland Park, New Jersey school district eliminated school bus service in response to a significant reduction in state funding and saved $100,000 per year in transportation costs. Cutting school bus service was possible because the town is small (1.9 miles^2) and nearly all residents live within 2 miles of school. In anticipation of the impact that busing cuts would have on the 110 students affected, the School Board and community partners implemented SRTS initiatives to improve safety. Schools designated walk-to-school routes and schools and parents organized Walking School Buses. Crossing guards were hired to assist with larger intersections along the walking routes. To encourage active transportation to school in lieu of driving, all four public schools also installed more bike racks and permitted students to store scooters, skateboards, roller skates, and other transportation equipment in the school office if they did not fit in lockers. Since 2008, Highland Park has also installed new sidewalks; raised and repainted crosswalks at key intersections and transit stops; and implemented traffic calming measures, such as curb extensions and pedestrian islands, to further improve the safety of walking and bicycling.

SRTS programs have also been used to reduce transportation costs by increasing the efficiency of bus routes. In June 2013, a Walking Bus Stop pilot program was launched for Russell Elementary School (Columbia, Missouri) to encourage children to walk together to a neighborhood school bus stop. Rather than having the school bus pick up and drop off children separately at their respective residences, the school bus stops for one neighborhood were consolidated into a single stop. Volunteer walk leaders led a walking group along a ¾-mile route to and from the school bus each day, picking up children at their residences along the way. The program showed that consolidating bus stops saved the district fuel, bus wear-and-tear, and 10 min of driver time for each bus trip to or from school. While this pilot program was implemented at a small scale with one neighborhood along one school bus route, the program demonstrated the ability for significant pupil transportation cost savings if scaled up to multiple neighborhoods per route along the more than 100 school bus routes that serve Columbia Public Schools.

In Auburn, Washington, investments in signage, sidewalks, paths, and traffic calming measures around schools improved the safety of local routes to school and reduced the need for hazard bus service. These interventions, coupled with SRTS-funded sidewalks and bike lanes, made it possible for 20 % of students in Auburn to walk or bike to school, saving the city $240,000 every year in hazard busing costs (Safe Routes to School National Partnership 2010). At one Auburn elementary school, the interventions resulted in 85 % of children walking or biking to school and allowed bus service to be reduced from six buses to one (Pullen-Seufert et al. 2009). Melrose Elementary in Wooster, Ohio similarly reduced hazard busing service in exchange for SRTS-funded sidewalks, crosswalks, and school zone signage (Pedroso et al. 2011). The reduced need for hazard busing saved the school district $49,000 per year. These cases demonstrate how Safe Routes to School investments can help school districts reduce pupil transportation costs and plan for tighter transportation budgets by creating safe walking and bicycling alternatives to school.

In 2014, the city of Austin constructed a pedestrian bridge over a creek to connect apartments serving low-income families with their elementary school located a half-mile away. The bridge cost $750,000 and was paid for by the City and federal grants. Prior to bridge construction, students were bused to school because there was no safe walking route. Because of the street configuration, school bus routes were at least 3 miles each way. With the bridge in place, the school eliminated several bus routes, saving $130,000 in annual busing costs. City and school officials also coordinated construction of the bridge with outreach efforts to teach students about safe walking and biking and provide students the opportunity to receive a free bicycle and training on bike safety in coordination with the City and the Police Department.

The Austin example highlighted two critical factors: coordination between the City and the school district and recognizing child safety as an important factor in deciding where to make pedestrian and bicycle improvements. In Austin, the Public Works department has a Child Safety program. This program receives funding from fees for vehicle registration, parking violations, and traffic violations that occur in a school zone and is responsible for pedestrian and bicycle safety education in the schools and for school crossing guards. Staff from the Child Safety Program work closely with school district pupil transportation staff to monitor school travel safety and identify opportunities to remove hazards. Because the Child Safety Program is located in the Public Works department, they are also uniquely able to address the need for improved child pedestrian safety in City of Austin Public Works projects.

Private costs: reduced passenger vehicle driving

Existing research shows that SRTS interventions have been successful in reducing motor vehicle trips to schools and the associated cost of that travel. A study on the Marin County SRTS program examined pre- and post-intervention walking and biking rates to school after implementing education and encouragement investments that included classroom education, walking and biking days, mapped routes, walking trains, and school newsletters. From 2000 to 2002, the number of children walking to school increased by 64 %; the number of students biking increased by 114 %; the number of students carpooling increased by 91 %; and the number of motor vehicles carrying one student decreased by 39 % (Staunton et al. 2003). Similar results were seen at Roosevelt Middle School in Eugene, Oregon, where a combination of infrastructure and non-infrastructure SRTS investments were made in crosswalks, school zone signage, a pedestrian path, and education and encouragement programs. The proportion of students walking and biking to school subsequently increased over a three-year period from 27 % in 2007 to 42 % in 2010. At the same time, the number of cars picking up children from school decreased by 24 % (Pedroso et al. 2011).

Since starting its Safe Routes to School program, Eagle College Preparatory in Phoenix, Arizona, has seen considerable increases in children walking and biking to school and reductions in family car trips. In 2010, just one percent of students walked to school. As of 2013, the proportion of children walking to school has increased to 12 %. At the same time, the drop-off and pick-up process for students who are driven to and from school has been streamlined. With more students walking and biking, the time it takes to unload and load students before and after school has been reduced by half. These improvements reduced the amount of time monitors are needed to supervise student loading zones, the number of cars idling and the length of time idling, and resulting emissions.

Results: analysis of school bus network impacts of SRTS programs

The busing simulation analysis performed in this study assessed how the amount of hazard busing combined with the local land use context influenced the costs of providing school bus service. At school A, with 92 % of students living within 1 mile, we found only one school bus was required with no hazard busing. However, providing hazard busing to all students living within 1 mile would require four additional buses (Table 5). The impact of hazard busing depended on the geographic context of the school. School D, located in a more suburban area where only 22 % of students lived within 1 mile, required five buses in the base case of no hazard busing, but only two additional buses if all children living within 1 mile of the school were bused.

The simulation suggested that the cost impacts of hazard busing can be significant. At School A, busing the 29 students who lived more than 1 mile from school would cost $60 per enrolled student per year. Per student costs increased substantially with hazard busing. Providing hazard busing to half of students living within 1 mile of School A would cost

Table 5 Number of students bused, bus vehicle miles of travel, and number of buses for all schools and scenarios

Hazard busing (HB)	# Students bused			Bus VMT			# of buses		
	0 % HB	50 % HB	100 % HB	0 % HB	50 % HB	100 % HB	0 % HB	50 % HB	100 % HB
School A	29	206	384	49	91	100	1	3	5
School B	155	379	603	103	122	181	3	6	10
School C	97	180	263	148	160	150	2	4	4
School D	354	406	459	212	290	294	5	6	7

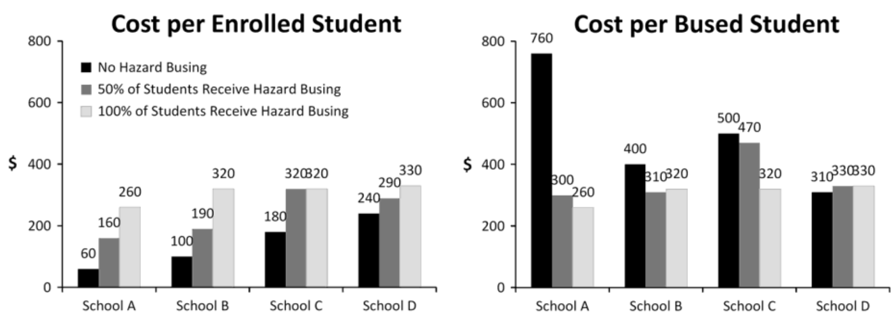

Fig. 1 School bus transportation costs by hazard busing scenario: per enrolled student and per bused student

$160 per enrolled student per year—an increase of $100 over the base case of no hazard busing (Fig. 1). Busing all students living within 1 mile would cost $260 per enrolled student per year. The magnitude of the per-student cost increase due to hazard busing decreased as fewer students lived within 1 mile. At School D, providing all students living within 1 mile with hazard busing cost 38 % more on a per-student basis than the base case of no hazard busing. These results suggested that reducing the need for hazard busing through infrastructure improvements could lead to cost savings. Investments in pedestrian and bicycle infrastructure would be most effective at reducing costs at schools with high amounts of hazard busing and large numbers of children that live within walking distance of school.

Providing hazard busing consistently led to an increase in aggregate and per enrolled student school bus expenses. However, some districts and states evaluate the efficiency of school bus provision by considering costs per bused student. For example, the cost per *enrolled* student (and therefore total costs) at School A was minimized when no hazard busing was provided. However, the cost per *bused* student at School A was $760 with no hazard busing but dropped to $260 when all students living near school received hazard busing (Fig. 1). The latter is clearly more costly overall, but assessing costs per bused student can obscure this fact. This point is not unimportant. Some states, such as North Carolina, reimburse districts based on the efficiency of their school transportation and this may provide an incentive to bus students living near school in order to minimize costs per bused student (Safe Routes to School National Partnership 2014).

Value of cost savings

Cost savings from eliminating hazard busing represent permanent cost savings to school districts. As such, it is appropriate to capitalize the savings over time. Over a relatively modest ten year period, eliminating hazard busing at School A is worth $860 per enrolled student if half of students are hazard bused (at a social discount rate of 3.5 %) (Table 6). For a 385 student school, this represents $330,000. Potential cost savings are lowest at the least-dense school, School D, due to residential location patterns that require substantially more busing and the smaller number of students living close to the school.

These cost savings compare favorably with the costs of improving infrastructure to eliminate the need for hazard busing. Table 7 details the costs of common SRTS improvements and makes clear that, in many contexts, an economic argument can be made

Table 6 Value of eliminating hazard busing

School	Enrollment	Annual cost savings	Net present value over 10 years	
		Per-student	Per-student	Per-school
School A	385	$100	$860	$330,000
School B	604	$90	$760	$459,000
School C	264	$140	$1,140	$301,000
School D	460	$50	$450	$206,000

Based on eliminating hazard busing to 50 % of students living within 1 mile

Table 7 Estimated cost of common SRTS infrastructure improvements

Item	Cost (median)	Unit
Bicycle rack	540	Each
Bicycle lane	89,470	Mile
High visibility crosswalk	3,070	Each
Striped crosswalk	340	Each
Rapid flashing beacon	14,160	Each
Median island	10,460	Each
Multi-use trail—paved	261,000	Mile
School crossing	520	Each
Concrete sidewalk	27	Linear foot
Crossing Guard	6,360	Intersection

Source Bushell et al. (2013, Appendix D)

for decreasing busing costs by making infrastructure improvements near schools. For example, if a dangerous road crossing prevents students from walking to school, the crossing could be improved with the addition of a high-visibility crosswalk, flashing beacon, and median island. The costs of these improvements are often substantially less than the present value of the costs of busing students over a ten-year period.

Discussion

School busing was introduced to allow students living far from schools to receive an education. However, as concerns about traffic safety and stranger danger have increased, the majority of children living within walking distance are now transported by bus or private vehicle. Leaving aside potential health benefits from increased walking and biking, the analysis presented in this paper suggests there are opportunities for cost savings for state departments of education, local school districts, families, and communities if these trends reverse. Schools can save money by eliminating hazardous conditions that make it difficult for many students to walk short distances to school. Families can eliminate the costs associated with private travel by walking or biking their children to school or collaborating with neighbors to ensure the safe movement of their children to school. Communities can save through reduced congestion near schools and the costs associated with exposure to air pollution.

The elimination of hazard busing through infrastructure investment can reduce the pupil transportation costs by an estimated $100–$500 million per year. If these children then walk or bicycle to school, these cost savings can be fully realized. If parents drive their children to school when hazard busing is eliminated, this will reduce costs to schools but have the unfortunate effect of increasing costs for families. Several school districts have used SRTS investments to eliminate hazard busing or address cuts in school busing through improved infrastructure. Austin, Texas provides a compelling example of how cities and school transportation departments can work toward a common goal of providing safe travel for children across multiple modes. This analysis also shows that the economic returns of SRTS investments are highest at schools where many students live within walking distance and could benefit from SRTS projects.

The difficulties associated with the argument that SRTS investments can save money by eliminating hazard busing are multidimensional and complicated by current institutional practices. In the United States, infrastructure improvements are generally the responsibility of the municipality or the state department of transportation. When school districts provide school bus service, the costs are borne locally and may be partially offset through reimbursements from the state department of education. So the costs and benefits of reducing hazard busing accrue to different agencies. Overcoming these barriers requires agreement between the city, schools, and parents that safe school travel requires busing for students living beyond a walkable distance and safe streets for students living close to school. Beyond the shared vision, cities and schools must also work together so that cities are aware of the need for infrastructure improvements and schools have advance warning about improvements.

State departments of education must also consider how pupil transportation assistance to districts encourages or discourages walking and bicycling. Our analysis highlighted how some reimbursement formulas that focus on costs per bused student might actually encourage inefficient busing practices among school districts. In order to reduce per-student cost calculations, districts may provide busing to students living near schools who might otherwise walk, thereby encouraging inefficient use of public resources. Simple fixes, such as including language that eliminates reimbursement for students living within walking distance, would remove this incentive and encourage school districts to work with municipal governments to eliminate hazardous walking conditions near schools.

Finally, the removal of hazard busing due to the elimination of dangerous conditions can only be considered fully successful if families utilize the infrastructure and children begin to walk and bike. If the removal of hazard busing simply shifts the costs of getting students to school onto families, then there is little benefit to society. Thus, schools and cities working together to identify and mitigate hazardous conditions is not enough; families must be part of the process as well. Cutting hazard bus routes—even if conditions no longer warrant them—can feel like cutting a public service to families. Unless the city and district communicate the proposed changes and provide extra services, such as crossing guards, to aid in the transition, families may not like the change and may even oppose implementation.

Further research related to the potential fiscal benefits of non-motorized infrastructure improvements is needed. Within the realm of children's travel, there is need for detailed analyses that calculate the changes in transportation costs resulting from SRTS investments. Studies analyzing the impacts of SRTS should begin to include economic factors and not only safety and travel behavior. Broader evaluations of the co-benefits of walking and bicycling should also consider the inclusion of fiscal dimensions, particularly related to public sector costs.

Conclusion

SRTS programs have been shown to be effective at increasing walking and bicycling, physical activity and safety. Most previous evaluations have focused on these metrics and their attendant health benefits. However, this paper has demonstrated that SRTS programs could also provide economic benefits by reducing the need to bus or drive students to overcome hazardous walking conditions. Opportunities for cost savings will vary with the local context. Investments in SRTS infrastructure will provide the largest financial benefit in situations where a large proportion of students live near the school and many of these students receive hazardous busing. While these results derive from the US context, the lessons apply whenever the public and private sectors pay for motorized transport to overcome hazardous walking conditions.

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Noreen C. McDonald is an Associate Professor in the Department of City and Regional Planning at the University of North Carolina at Chapel Hill. Her research interests include travel behavior and infrastructure planning.

Ruth L. Steiner is a Professor in the Department of Urban and Regional Planning and Director of the Center for Health and the Built Environment at the University of Florida. Her research focuses on the coordination of land use and transportation and its impact on communities, health and the environment.

W. Mathew Palmer is a Doctoral Student in the Department of City and Regional Planning at the University of North Carolina at Chapel Hill. His research interests include school travel behavior and educational facility planning.

Allison N. Bullock is a Planner at Alta Planning + Design, where she specializes in bicycle, pedestrian, and complete streets planning. She received a Master's in City and Regional Planning from the University of North Carolina at Chapel Hill in May 2013.

Virginia P. Sisiopiku is an Associate Professor in the Department of Civil, Construction, and Environmental Engineering at the University of Alabama at Birmingham. Her research interests include traffic operations and safety and sustainable transportation.

Benjamin F. Lytle is a planner in the Orlando office of AECOM. He received a Master of Arts in Urban and Regional Planning from the University of Florida in August 2014.