



Assessing multimodal school travel safety in North Carolina



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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.

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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

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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 (Agron 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 walking and 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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