Cost-Effectiveness of Lap/Shoulder Seat Belts on Large Alabama School Buses

A Portion of the
ALABAMA SCHOOL BUS SEAT BELT PILOT PROJECT
conducted for the
Alabama State Department of Education
and the
Governor's Study Group on School Bus Seat Belts

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16. Abstract

This report presents a cost-effectiveness analysis of school bus seat belt implementation in Alabama. The study was patterned after the methodology used in a 2008 National Highway Transportation Safety Administration (NHTSA) report prepared for a regulatory analysis of potential school bus safety enhancements.

School buses are already the safest vehicles on the road. NHTSA reports "school buses are approximately seven times safer than passenger cars or light trucks." In recent years Alabama school buses have averaged 560 traffic crashes per year while driving many miles (83 million route miles in 2009-2010). As a result, the rate of bus crashes per mile driven is well below that of other vehicles in the state. Also, school buses have many fewer fatal crashes than other Alabama vehicles. Since 1976 – when NHTSA required school bus compartmentalization to improve safety – traffic crashes have caused only five fatalities to pupils inside Alabama school buses.

Noteworthy reports that guided this study were prepared by the National Academies Transportation Research Board, the American Academy of Pediatrics, and NHTSA. During the Pilot Project, UA researchers collected data on seat belt use rates, differences in national and Alabama fatal school bus crashes, and loss of school bus capacity due to seat belt installation.

For this project, the Alabama State Department of Education (ALSDE) collected data on costs for school bus maintenance and operation, the cost to purchase new any of four school bus seating configurations (some with seat belts), and the cost to purchase school buses with an extended passenger compartment to offset loss of seats due to thicker seat backs.

The benefits of school bus seat belts are reductions in fatalities and injuries. It was difficult to obtain enough of these data to achieve statistical validity, so University of Alabama (UA) researchers adopted the crash pattern for national school bus fatal crashes as a proxy for the Alabama pattern. The UA researchers used NHTSA's (2008) methodology to convert Alabama crash data to the Maximum Abbreviated Injury Scale (MAIS) so the costs of treatment and prevention could be estimated. Then they estimated the number of injured and fatalities for various types of crashes to generate cost savings of seat belts.

The study produced an estimate of injury and fatality reductions assuming 100% seat belt use on all buses. However, in observing over 125,000 individual pupils inside school buses, UA researchers found the seat belt use rate was only 61.5%, so they reduced their estimates of injuries and fatalities by 38.5%. The analysis estimates school bus seat belts will reduce fatalities by 39% and injuries by 13%, resulting in 0.13 fatalities and 7.60 injuries prevented each year.

The Office of Management and Budget (OMB) requires all federal agencies to perform cost-effectiveness analyses for proposed rule-making. NHTSA (2008) conducts two types of such analyses: a cost-effectiveness estimate that measures the cost per equivalent life saved – "the sum of fatalities and nonfatal injuries prevented converted into fatality equivalents" (NHTSA 2001) – and a measure of net benefit in monetary value. Because future values of benefits are included in the analysis, they are discounted using a reasonable range of discount rates. NHTSA assigns comprehensive costs to injuries and fatalities to yield an economic Value of a Statistical Life (VSL). This is a well-documented procedure; see NHTSA (2008) for more.

Using the NHTSA methodology and VSL, along with the costs and benefits documented in this report, UA researchers reached several conclusions:

- The cost of an equivalent life saved from Alabama seat belt implementation of the least expensive seat configuration is $32 million to $38 million.
- The net benefits from seat belt implementation over one cycle of fleet life range from -$104 million to -$125 million. The benefits are negative because the costs are larger than the benefits.
- School bus seat belts are not as cost effective as other types of safety treatments.
- The most cost-effective configuration with seat belts has an extended passenger compartment to accommodate 12 rows with 3 flex seats on both sides of the aisle. The least cost-effective configuration with seat belts has 11 rows with 3 fixed seats on one side of the aisle and 2 on the other.

Alternative Safety Treatments

The literature indicates there are more pupil fatalities in loading/unloading zones than inside school buses, and Alabama crash data confirm this pattern. ALSDE has collected records that indicate many vehicles pass stopped school buses that are loading or unloading pupils despite a state law requiring such vehicles to stop during loading/unloading.

Most school bus pupil fatalities occur outside buses in or near loading zones. It appears more lives could be saved by investing in enhanced safety measures in loading/unloading zones rather than in installation of seat belts. These treatments are also less expensive than seat belts. The report provides eight examples, including training, better technology, and greater enforcement of violations of the no-passing law.

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Executive Summary

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Section 1
Introduction

1.1 Objective

The University Transportation Center for Alabama (UTCA) conducted the Alabama School Bus Seat Belt Pilot Program for the Governor's Study Group on School Bus Seat Belts (Governor's Study Group) and the Alabama State Department of Education (ALSDE). The overall goal of this project was to explore the implementation of lap/shoulder belts on newly purchased large school buses in Alabama. This includes determining the rate of seat belt use, the effects on bus discipline, the attitudes of stakeholders, the loss of capacity attributable to seat belts, the cost effectiveness of the belts, and other pertinent issues.

This portion of the project seeks to determine the cost effectiveness of requiring lap/shoulder seat belts in all newly purchased large school buses in Alabama. This study is part of the overall Pilot Program.

1.2 Impetus for the Project: the Huntsville, Alabama, Crash

The Pilot Program was initiated following a 2006 Huntsville, Alabama, school bus accident that killed 4 pupils and injured 34 more. The following description of the crash was taken from the National Transportation Safety Board's (NTSB) *Highway Accident Brief* (2009):

> The National Transportation Safety Board determines that the probable cause of the November 20, 2006, accident in Huntsville, Alabama, was a vehicle loss of control during a passing maneuver around a curve by the Toyota driver attempting to overtake the school bus prior to an impending exit both drivers intended to take. Contributing to the severity of the accident was the restricted trajectory of the school bus away from the bridge rail due to the presence of the Toyota, which resulted in the bus overriding the rail and falling 30 feet from the elevated highway access ramp to the ground.

The accident stimulated Alabama Governor Bob Riley to create a study group to investigate school bus seat belts. The group found that there were virtually no data (safety effectiveness, belt use rates, configuration/capacity issues, cost effectiveness, etc.) on this vital topic. The group made two decisions. First, it decided not to make any decision that made the situation worse (that is, "do no harm"). Because school buses are the safest form of transportation for pupils to and from school, the group wanted to avoid pushing students to less-safe alternatives. Second, the group felt more information was needed and recommended Alabama initiate a school bus seat belt pilot program to collect data for decisions about the belts.

After reviewing the recommendations of the Governor's Study Group, the Alabama Legislature authorized $1.4 million dollars to conduct a pilot project assessing the effects of lap/shoulder belts on occupant safety. ALSDE used a portion of the funds to purchase 12 type C and type D school buses for 10 strategically chosen local school systems. The buses were fitted with three- and four-point restraints and ceiling-mounted digital camera systems. ALSDE also paid the operating costs of all 12 buses, which included drivers for each bus and aides for half of them.

The study group and ALSDE prepared a request for proposals, and after evaluation of competitive proposals, awarded the project to two research centers at the University of Alabama: UTCA and the Center for Advanced Public Safety (CAPS). Since then the centers have worked jointly on the three-year project.

1.3 School Bus Travel In Alabama

Public-school transportation is a large and costly operation in Alabama. About 51% of the state's 741,115 pupils rely daily on public school buses to travel to and from school (ALSDE 2010a). The 7,341 school buses that transport them average 51 pupils each and together travel 457,258 miles daily (82.3 million miles annually). Compared to school buses across the nation, Alabama school buses are young and in good condition, with 97% of them 10 years old or less.

The estimated annual cost of pupil transportation is $329,164,593, or $873.93 per pupil transported. It costs $4.86 to transport each pupil each day, which is $4.00 per pupil bus mile.

1.4 Overview of School Bus Safety in Alabama

It is generally accepted that school bus travel is the safest form of surface transportation in the nation, and Alabama data support that. School buses provide protection because of their visibility, size, and weight. Additional protection was added through compartmentalization in 1976 under Federal Motor Vehicle Safety Standard (FMVSS) 222 (NHTSA 2008). Compartmentalization provides crash protection for children on large school buses with strong, closely spaced seats that have energy absorbing backs to protect children from front- and rear-end crashes (Lindly, et al. 2008).

Between 1976 (when school bus compartmentalization was first required) and 2010, five pupils inside Alabama school buses were killed in crashes. The first fatal school bus crash in the data occurred in 1998 and the second occurred in 2006 (the Huntsville crash). In the first 22 years of the 34-year period there were no pupil fatalities inside Alabama school buses, in the next 8 years there were five, and in the final 4 years there were none.

This data pattern has two clear implications. First, fatal school bus crashes are rare in Alabama, especially compared to other types of crashes. Only 2 school bus crashes in 34 years were fatal to the pupils inside, so on average a fatal school bus crash occurs every 17 years. These 2 crashes caused 5 fatalities, which averages about 1 pupil fatality every 7 years.

Second, there is great variability in the pattern of their occurrence. There was a 22-year stretch without a pupil fatality inside a school bus, but then 5 were killed in the next 8 years. *For this* *study it is important to note that it is impossible to statistically predict the number of fatalities in a given year. In fact, the number of pupil fatalities in Alabama school buses is so small that statistical analyses are impossible.*

Of course these implications do not diminish the tragedy and anguish associated with these pupil deaths. But they do clearly establish that such fatalities are rare events from a statistical standpoint.

Additional information about school bus crashes in Alabama may be found it Tables 1-1 and 1-2. Table 1-1 was prepared from the files of the ALSDE Pupil Transportation Section (ALSDE 2010b). The average number of bus crashes per year (560.6) and average number of injuries to pupils and drivers each year (81.2) may seem large, but they can be attributed to the number of bus miles driven per year (82.3 million).

Another conclusion can be drawn from Table 1-1. In school bus crashes, 4 pupils were killed inside school buses while 20 people were killed outside school buses (pedestrians, drivers and occupants of other vehicles involved in school bus crashes, etc).

Table 1-1. Sample Alabama school bus crash statistics

School Year	School Bus Crashes	Pupils Injured	Bus Drivers Injured	Others Injured, Outside Bus	Fatalities, Pupils In Bus	Fatalities Outside Bus	All Fatalities
2000-01 thru 2008-09	5045	640	91	253	4	20	24
Ave/year	560.6	71.1	10.1	28.1	0.45	2.2	2.7

Source: ALSDE (2010b)

Table 1-2. Comparison of Alabama traffic crash statistics: school buses vs. all vehicles

Data	Fatalities	Injuries	Crashes	Miles Traveled
All vehicles 2008 (ALSDE 2010b)	964	35,619	123,969	54,148,000,000
School buses, Ave. 2001-02 to 2008-09 (CAPS 2008)	2.7	81	561	83,300,000
Buses as % of all vehicles 2008	0.28%	0.23%	0.45%	0.15%

Table 1-2 provides another perspective on the number of school bus crashes, injuries, and fatalities. Although large numbers, they are miniscule compared to the overall traffic safety and vehicular travel picture in Alabama. That does not diminish the importance of pupil fatalities in school buses, but it does clarify the overall highway-safety problem in Alabama.

Another way to analyze Alabama public school bus safety is through a comparison of fatality rates. In the 34 years of data adopted for this study, five pupils died inside school buses as the result of a crash. This is equivalent to 0.15 deaths per year. Assuming Alabama school buses traveled 3% more miles each year – which is normal growth for Alabama traffic – there were 0.28 pupil fatalities per 100 million vehicle miles traveled (100MVM). This Alabama school bus fatality rate is identical to the national school bus fatality rate, but it is much lower than the national motor-vehicle rate (1.37 per 100MVM) and the Alabama 2008 motor-vehicle rate (1.63 per 100MVM) (CAPS 2008).

1.5 National Issue

Although this report was prepared to address the potential adoption of school bus seat belts in Alabama, it has greater implications. American attitudes have clearly shifted toward requiring lap-shoulder belts to make school bus travel safer for pupils.

There are questions about the effectiveness of the belts. Examples include the degree to which the lap/shoulder seat belts may reduce school bus injuries and fatalities, the loss of capacity in school buses, the age of pupils that will use the belts, the additional funds needed to implement their use, and especially the cost effectiveness of school bus seat belts.

This report addresses school bus seat belt cost effectiveness. Other parts of the Alabama School Bus Seat Belt Pilot Program address other important pertinent issues and the relevant data. A list of the Alabama School Bus Seat Belt Pilot Program reports dealing with these issues is in the appendix.

1.6 Summary

This portion of the report has provided background information to explain why the overall project was conducted and to frame general issues involving school bus safety in Alabama. Several conclusions can be drawn from this information:

- The Governor's Study Group found there were virtually no data about school bus seat belts (safety effectiveness, belt-use rates, configuration/capacity issues, cost effectiveness, etc.) on this vital topic.
- It is generally accepted that school bus travel is the safest form of surface transportation.
- School buses provide protection due to their visibility, size, and weight.
- In 1976 federal regulations provided additional safety to school buses by adding compartmentalization.
- There were two fatal school bus crashes and five pupil fatalities inside school buses between 1968 and 2010.
- Fatal school bus crashes are rare in Alabama, especially compared to other modes of surface transportation.
- Starting in 1976, when new compartmentalization standards took effect, there were no fatalities for 22 years, 5 in the next 8 years, and none in the last 4 years.
- It is statistically impossible to predict the number of fatalities in a given year. The number of fatalities to pupils in school buses in Alabama is so small that statistical analyses are impossible.
- There is great variability in fatal school bus crash patterns.
- The number of annual school bus crashes, injuries, and fatalities seem large, but the numbers are driven by 83.2 million miles of annual school bus travel. They are miniscule compared to crashes, injuries, and fatalities of other travel modes.

The following sections of the report review prior studies, discuss available data, discuss the study’s methodology, document the application of the cost-effectiveness procedure to Alabama data, and draw conclusions.

Section 2
Literature Review

There has been great interest in school bus safety, but limited data have hindered progress in understanding school bus crash safety. Three national studies of school bus fatalities have been conducted by NHTSA, and two landmark studies have been conducted by the Transportation Research Board of the National Academies (formerly the National Academy of Sciences, or NAS). This section briefly reviews the portions of those five studies pertinent to the Alabama School Bus Seat Belt Pilot Project, along with other studies that provide data, facts, or perspectives useful to the project.

2.1 NTSB SS-86-03

The National Transportation Safety Board (1987) conducted a detailed analysis of school bus crashes and found little benefit could be attributed to lap-shoulder belts in severe crashes. NTSB estimated the belts might produce a 20% reduction in fatalities and injuries. The report stated that "the overall benefits of requiring seat belts on large school buses are insufficient to justify a federal requirement for mandatory installation." It also found that "the funds used to purchase and maintain seat belts might be better spent on other school bus safety programs and devices that could save more lives and reduce more injuries."

2.2 NAS Report 222: *Improving School Bus Safety*

The 1987 Surface Transportation and Uniform Assistance Act authorized the NAS to investigate the principal causes and injuries to pupils riding in school buses. NAS assigned the study to one of its units: the Transportation Research Board (TRB).

Special Report 222 (National Academies 1989) reviewed the effectiveness of lap belts (not lap/shoulder belts) in reducing injury in school bus crashes through statistical evaluation of lap belts in the rear seat of passenger cars, crash tests, sled tests, and real-world crashes. The following notes and conclusions from the report are pertinent:

- The effectiveness of lap belts in passenger cars implies lap belts in school buses might reduce the number of fatalities by 20% and the number of serious and fatal injuries by 40%.
- Crash tests and sled tests were inconclusive about belt effectiveness in front collisions of school buses.
- Dummies restrained by lap belts during crash tests sustained reduced levels of chest damage but higher levels of head damage.
- TRB researchers noted a detailed NTSB (1987) study of the potential effectiveness of lap belts in severe school bus crashes suggested little to no benefit could be attributed to lap belts.

- The benefits of requiring seat belts on large school buses are insufficient to justify a federal requirement for mandatory installation.
- The funds used to purchase and maintain seat belts might be better spent on other school bus safety programs and devices that could save more lives and reduce more injuries.

The overall sentiment of Special Report 222 was that lap belts had limited effectiveness as a preventive measure for the safety of children riding school buses. Indeed, lap belts may make accidents more dangerous because of the increased risk of head injuries.

2.3 NAS Special Report 269: *The Relative Risks of School Travel*

The Transportation Equity Act for the 21st Century called for TRB to evaluate "the safety issues attendant to the transportation of school children to and from school and school related activities by various transportation modes." The TRB's Committee on School Bus Transportation oversaw the study, which used data from the Fatal Analysis Reporting System (FARS) and the National Automotive Sampling System (NASS) General Estimates System (GES) for 1991 to 1999.

Special Report 269 (TRB 2002) included a risk table for common transportation modes in terms of fatalities (F/100MSM) and injuries (I/100MSM) per 100 million student-miles. This information is displayed in Table 2-1, which shows the overall rate is 0.70 F/100MSM, while the rate for school buses is 0.06 F/100MSM.

Table 2-1. Estimated student injuries and fatalities and rates by mode of transportation during normal school travel hours

Mode	Fatalities (%)	Injuries (%)	Fatalities/100 M Student Miles	Injuries/100 M Student Miles
School Bus	20 (2%)	6,000 (4%)	0.06	19
Other Bus	1 (<1%)	550 (<1%)	0.03	14
Passenger Vehicle, Adult Driver	169 (20%)	51,000 (33%)	0.30	88
Passenger Vehicle Teen Driver	448 (55%)	78,200 (51%)	2.40	430
Bicycle	46 (6%)	7,700 (5%)	12.20	2,050
Walk	131 (16%)	8,800 (6%)	8.70	590
Total	815 (100%)	152,250 (100%)		
Overall			0.70	130

Source: extracted from TRB (2002)

The fatality and injury rates in the table show school buses and other buses are far safer than other modes of school transportation. Students are 6 times more likely to be killed while traveling in a passenger vehicle driven by an adult than in a school bus and 48 times more likely while traveling in a passenger vehicle driven by a teen.

Special Report 269 found 75% of school bus fatalities involved pedestrians (pupils loading and unloading). It concluded that the risk factors associated with these modes are "complex and highly interrelated" and that any change of school travel mode could lead to dramatic changes in the overall risk for the students.

2.4 American Academy of Pediatrics School Bus Injury Epidemiology Study

The American Academy of Pediatrics (AAP) conducted a study to classify non-fatal school bus-related injuries among children aged 19 or younger (McGeehan, et. al. 2006). The study data included the National Electronic Injury Surveillance System All-Injury Program (NEISS-AIP), maintained by the US Consumer Product Safety Commission. The study used information about people treated in hospital emergency rooms in 2001-2003. The researchers estimated annual rates by age group and injury rates for nonfatal school bus related injuries. The results are shown in Table 2-2.

Table 2-2. Non-fatal school bus-related injuries treated in hospital emergency departments by age (2001-2003)

Age	Annual count/ 100,000 children	%	Rate per 100,000 children	95% confidence level
0 – 4	702	4.1	--	--
5 – 9	4,654	27.3	23.3	15.9 – 30.7
10 – 14	7,316	43.0	34.7	25.9 – 43.6
15 – 19	4,361	25.6	21.4	13.7 – 29.2
Total	17,033	100	21.0	--

Source: McGeehan, et. al. (2006)

The AAP estimated 17,000 injuries annually, 97% of which the children were treated and released from the hospital. Children between 10 and 14 years old experienced the greatest number (7,316) and highest rate (34.7%) of injuries. The study also analyzed the injury mechanism, body-area injured, injury diagnosis, and outcome. This information is useful in relating school bus injuries to the results of crash tests and sled tests and in establishing estimates of treatment costs for various levels of injury.

The emergency-room data identified 5% more school bus injuries than shown in the NHTSA data, which reflect data only from traffic-related crash injuries. When safety belts are being considered, one could increase the NHTSA estimate of traffic related injuries by 5% to account for non-traffic related injuries.

Table 2-3. Non-fatal school bus-related injuries treated in hospitals and emergency departments by body region (2001-2003)

Injured body region	Annual injury count	%
Head	5,031	29.5
Neck	2,420	14.2
Chest	2,856	16.8
Upper Extremity	2,608	15.3
Lower Extremity	3,624	21.5
Other/Not Stated	493	2.9

Source: McGeehan, et. al. (2006)

The AAP study also identified the distribution of injuries to body regions for school bus pupils. This information is shown in Table 2-3. This information is useful because it relates to the extent of MAIS injury. For example, the head, neck, and chest contain vital organs. Injuries to these regions are more likely to be life threatening than injuries to the extremities. Because pupil ages are known for both Tables 2-2 and 2-3, they may be merged to produce a table of injuries by age and body region. This provides a data set for evaluating seat belt effectiveness.

2.5 Prior NHTSA Studies of School Bus Crashes

Two NHTSA publications are directly pertinent to this cost-effectiveness study. They contain school bus fatality data from overlapping 11-year periods. They provide a way to directly relate Alabama school bus fatality data (too small a data set for statistical analysis) to national school bus data, which can be statistically analyzed.

The first is the school bus portion of NHTSA's *Traffic Safety Facts* (2006), which includes data from 1996 to 2006. The data include bus point of impact (for example, front) for 76 national fatal crashes resulting in 93 fatalities in full-size school buses. This enabled comparisons between national and Alabama fatal crashes based on the point of impact.

The second is NHTSA's (2002) report to Congress: *School Bus Safety: Crashworthiness Research*. The data covered calendar years 1990 to 2000 and included 55 fatal crashes involving 83 fatalities in all school bus types, 66 of which were in full-size buses. The number of crashes in full-size buses was not reported but can be estimated using the fatalities-per-fatal-crash ratio from NHTSA's (2006) *Traffic Safety Facts.* This assumption implies that only 17 fatal crashes involved van-based student transport. These data were tabulated by crash event (for example, rollover), which allowed comparison between Alabama and national fatal school bus crashes in the same manner used for the point-of-impact analysis described in the prior paragraph.

A more thorough discussion of these two articles is in Brown and Turner (2009).

2.6 Alabama-Specific Studies

Two studies consider Alabama school bus crashes. The first was conducted by Turner, Jones, and Woods (2005). It briefly reviewed Alabama school bus crashes between 1999 and 2003 and provided a general understanding of these crashes. The study data included all vehicles in school bus-related crashes, not just school buses. Of the 1,876 crashes in the data, only about 15% included injuries and less than 0.5% included fatalities. These rates are far below the rates for other types of vehicles involved in crashes in Alabama. Most of the crashes occurred at low speeds in school zones and were caused by other vehicles. The study also analyzed injury and fatal crashes to identify trends and causes. No type of crash was dominant, with run-off-road, pedestrian, left-turn-into-traffic, and fail-to-heed-stop-sign crashes occurring with some frequency.

The second Alabama study is the safety-effectiveness report generated as part of this project (Brown and Turner 2009). It noted the lack of crash data for school buses equipped with seat belts constrains determinations of seat belt safety effectiveness and cost effectiveness. The movement toward installing the belts is relatively new, and there are too few cases to generate a reasonable database. However, the researchers identified two attributes (point of impact and crash event) of school bus fatality data that could be combined with Alabama school bus crash data. Certain effects were quantified by comparing national school bus fatality data to Alabama school bus fatality data on these same attributes. A subset of Alabama school bus injury crashes provided a second comparison to reinforce the initial finding.

While there were insufficient data to generate statistically significant quantitative estimates of fatality reductions, the analysis generated results with a high degree of certainty:

- The greatest benefit of school bus seat belts is to bus occupants when the bus suffers a front point of impact.
- This benefit is lessened somewhat when the item struck is another vehicle; it is increased when the item struck is fixed (for example, a tree, pole, or bridge abutment).
- Benefits from seat belts are lessened when the school bus sustains a strike on the side or in the rear.

The authors used these findings, proxy values, and reasonable assumptions to estimate the safety effectiveness of school bus seat belt use. It estimated fewer than 2 lives will be saved each decade if seat belt use were 100% on every school bus across the state.

2.7 Summary of Literature Review

This section of the report reviewed several publications applicable to a cost-effectiveness study of school bus seat belts. The following are examples of key findings identified through this effort:

TRB Special Report 222 (1989)

- The effectiveness of <u>lap belts</u> in passenger cars implies lap belts in school buses might reduce the number of fatalities 20% and the number of serious and fatal injuries 40%.
- A detailed NTSB study (1987) of the potential effectiveness of lap belts in severe school bus crashes suggested little benefit could be attributed to lap belts.
- The overall benefits of requiring seat belts on large school buses are insufficient to justify a federal requirement for mandatory installation.
- The funds used to purchase and maintain seat belts might be better spent on other school bus safety programs and devices that could save more lives and reduce more injuries.

TRB Special Report 269 (2002)

- Risk factors associated with pupil transportation modes are "complex and highly interrelated," and any change in pupil travel mode could lead to dramatic changes in overall risk for the students.
- School buses are far safer than other modes of school transportation. Pupils are 6 times more likely to be killed traveling in a passenger vehicle driven by an adult and 48 times more likely traveling in a passenger vehicle driven by a teen.
- About 75% of school bus fatalities involved pedestrians (pupils loading and unloading).

AAP School Bus Injury Epidemiology Study (2006)

- There are 17,000 to pupils in school bus crashes annually, with 97% treated and released from the hospital.
- The 10-14 age group experienced the greatest number and rate of injuries.
- The study analyzed injury mechanisms, body-regions injured, injury diagnoses, and outcomes. This information is useful for relating school bus injuries to the results of crash tests and sled tests and in establishing estimates of treatment costs for various levels of injury.
- Emergency-room data identified 5% more school bus-related injuries than did NHTSA files. For analyses when safety belts are being considered, NHTSA's estimate of injuries can be increased by 5% to account for non-traffic related injuries.

NHTSA* Traffic Safety Facts *(2006)

- *Traffic Safety Facts* identified 76 national fatal crashes between 1996 and 2006 resulting in 93 fatalities. These data are appropriate for statistical analyses, while the small Alabama data for fatalities (2 fatal crashes and 5 fatalities in 34 years) are not.
- Fatal school bus crashes were tabulated by point of impact. Point-of-impact data are also available for Alabama crashes. They allow direct comparison of national and Alabama school bus fatal crashes, so inferences can be drawn about where Alabama data are similar or different from national data.

NHTSA Report to Congress* - School Bus Safety: Crashworthiness Research *(NHTSA 2002)

- This document identified 38 national fatal school bus crashes between 1990 and 2000, resulting in 66 fatalities in full-size school buses. Again, these data are appropriate for statistical analyses, while the small number of Alabama school bus fatal crashes is not.
- Fatal school bus crashes were tabulated by crash event (for example, rollover). As with the point-of-impact data, the same variable is available for Alabama crashes. It allows direct comparison of national and Alabama school bus fatal crashes so other important inferences can be drawn about school bus crashes.

Alabama Study (Turner, Jones, and Woods 2005)

- This study reviewed four years of school bus-crash data. All vehicles involved in school bus crashes were included.
- Less than 15% involved injuries and less than 0.5% involved fatalities. These are much lower than the rates for other types of vehicles used in Alabama.
- Most school bus crashes occurred at low speeds in school zones and were caused by other vehicles, not buses.
- For injury and fatal crashes, no single type of crash was dominant.

Alabama Study (Brown and Turner 2009)

- This study used national data for school bus fatalities (NHTSA 2002, 2006) to infer similarities and differences between Alabama and national fatal school bus crashes. Three primary findings emerged:
    - The greatest benefit of school bus seat belts in Alabama is to occupants involved in crashes with a front-end bus impact.
    - This benefit is lessened somewhat when the item struck is another vehicle; it is increased when the item struck is fixed (for example, a tree, pole, or bridge abutment).
    - Benefits from seat belts are lessened when the school bus sustains a strike on the side or the rear.

Although there are few significant studies on this topic, these findings can be analyzed collectively to frame the issue and move toward a solution.

Section 3
Methodology

UTCA researchers adopted the cost-effectiveness methodology utilized by NHTSA in safety studies and in reports that support its federal rule-making process. The most recent example is NHTSA (2008).

A simple overview of the methodology is shown in Table 3-1. A more detailed version is in the appendix. In general, the methodological steps are addressed in sequence in this report.

Table 3-1. Outline of cost-effectiveness methodology used in the Alabama pilot project

1	Define the specific goal(s) of the study
2	Identify sources of potential benefits and costs and the data needed to conduct the study
3	Determine if data are available and in the appropriate format (crash, fatality, and injury statistics on the MAIS scale)
4	Determine the effectiveness of available countermeasures
5	Apply safety-effectiveness ratios of countermeasures to determine potential lives saved and injuries prevented
6	Determine the costs of implementation
7	Determine the benefits – NHTSA Value of a Statistical Life
8	Determine the Benefit/Cost ratio, and the time value of benefits
9	Identify best use of funding (including alternative safety uses, if appropriate)
10	Summarize study and prepare recommendations

3.1 Goal of the Study

This study was conducted to determine the cost effectiveness of school bus seat belts. A cost-effectiveness analysis needs to consider the configuration of seats, sizes/ages of pupils, seat belt use rates, anticipated crashes, and reductions in crash severity, and other factors.

Section 4
Data

4.1 Costs of School Bus Seat Belts

In the simplest terms, data are needed to establish the costs of any changes needed for existing fleets to install seat belts. The costs include the seats that support seat belt use on new buses (the belts cannot be retrofitted because special seats are needed and the undercarriages of existing school buses were not designed to anchor them); additional buses needed to offset loss of existing bus capacity due to seat belt installation; and the additional drivers, aides, fuel, maintenance, insurance, and other routine operations needed for the additional buses.

ALSDE compiled the needed cost information from its records and from quotes obtained from school bus manufacturers. This information, which reflects the 2009-2010 school year, is shown in Table 4-1.

Table 4-1. ALSDE average 2010 costs for school bus purchase and operation

Expense Category	Cost
New school bus, average cost	$79,890
Operating costs – annual fuel per bus	$4,867
Operating costs – annual maintenance/other per bus	$3,106
Average salary/wages – driver:	$14,106/$12,165; total $26,271
Average salary/wages – aide:	$10,092/$12,165; total $21,443
Additional cost of seat belts	
3/3 with max seat spacing:	$12,000
3/3 without max spacing:	$15,000
3/2 with max seat spacing:	$11,000
3/2 without max spacing:	$13,000
Additional cost of extending passenger compartment to offset loss of a row of seats due to thicker seat backs	$1,000
Fleet replacement cycle is 10 years Growth/year: Pupils transported = 0%; Buses purchased =0%; miles traveled = 1.1%	

4.1.1 Impact of Seat/Row Configurations on Capacity and Cost

This study involves type C and type D school buses, which can be manufactured in different lengths. This means that there are more rows of seats on some buses than others. The most common size in Alabama carries 71 to 72 pupils (12 rows), so to simplify the discussion of loss of capacity, a 12-row school bus is used as an example.

Typically 39-inch-wide bench seats are on each side of the aisle. Each bench can hold three small pupils (elementary-school pupils) or two larger pupils (middle-school or high-school pupils, so a 12-row bus can hold 72 elementary-school pupils or 48 older pupils. Because three elementary-school pupils can sit on each side of the aisle, this is called a 3/3 configuration. In this report a bus with 3 elementary-school students pupil on both benches with 12 rows is referred to as a 3/3-12 configuration.

Seat belts can cause loss of school bus capacity in two ways. First, the belt-buckle latches are installed 15 inches apart, which makes it impossible to seat three elementary-school pupils on one 39-inch bench seat. To address the 15-inch fixed width of belt latches, manufacturers place three seats on one side of the bus and two on the other (a 3/2-12 configuration). This causes a loss of one seat per row. Other seat manufacturers have developed a slightly wider seat for three elementary-school pupil that has an adjustable middle belt latch so it can also seat two larger pupils. This type of seat causes a loss of aisle width.

Second, seats backs that accommodate seat belts are two to four inches thicker than current seats. A 12-row bus needs to be 24 to 48 inches longer to accommodate 12 rows or lose one or two rows to accommodate the belts. Lengthening the bus passenger compartment requires moving the rear axle backward, resulting in a larger turning radius for a large bus. This could be problematic in controlling a bus in a small parking lot with sharp turns.

Gurupackiam, et al. (2010) analyzed the effect of seat belt installation on 2,222 buses (30% of the Alabama fleet) with manufacturer's ratings of 71 or 72 pupils using existing pupil loads and four proposed seat configurations. The configurations represent the current seat and row arrangement (3/3-12 configuration), loss of a row of seats (3/3-11), loss of one seat per row (3/2-12), and loss of both a row of seats and a seat per row (3/2-11). The authors created a methodology that considered pupils' ages (that is, sizes) for each bus to determine whether the bus has enough reserve capacity to carry its current pupil load once seat belts were installed. Using this method, UTCA researchers determined the number of additional buses needed, as shown below:

3/3-12 configuration: currently running with 3% of buses overloaded
3/3-11 configuration: 16% more buses are needed to carry current pupils
3/2-12 configuration: 7% more buses are needed to carry current pupils
3/2-11 configuration: 20% more buses are needed to carry current pupils

A thorough analysis of the data indicated that the estimated number of required new buses may be over by up to 2%. For this reason, Gurupackiam, et al. (2010) recommended using 1%, 14%, 5%, and 18% of additional buses for the four configurations respectively.

Another consideration is that two manufacturers can provide flex seats. Flex seats are slightly wider than conventional seats and have a movable middle belt latch that can be adjusted to fit two large or three small pupils. Depending on the length of the bus purchased and the seat spacing, a flex-seat bus would lose one row of seats or a bench on one side of the bus. This approximates the 3-3/11 configuration or the 3-3/12 configuration less one bench.

To facilitate the cost-effectiveness analysis, ALSDE managers obtained price quotes for all four seat configurations. The new buses needed under each configuration capacity must be considered in the cost-effectiveness study.

4.2 Benefits of School Bus Seat Belts

The primary benefits of school bus seat belts are fewer fatalities and serious injuries when crashes occur and fewer discipline issues due to keeping pupils in their seats.

Situations requiring disciplinary actions by school bus drivers or aides were observed infrequently during this study. Without the advantage of observing a group of control buses without seat belts, UTCA researchers were unable to determine the degree to which discipline improved due to seat belt installation. For this reason, the cost-effectiveness study did not consider the effects of seat belts on discipline.

4.3 Crash Data Needed for Study

The primary benefit of seat belts is reduction of fatalities and serious injuries. One way to look at this is the belts reduce a portion of the fatalities to injuries and a portion of the serious injuries to minor injuries. Fatalities and serious injuries decrease, minor injuries may increase, and hopefully fewer crashes lead to injuries.

The specific data needed for this study are the numbers of fatalities and injuries to pupils inside school buses when crashes occur. Drivers are not considered because they have been required to wear seat belts for years. Pupils outside the bus when the crash occurs are not considered because the belts cannot help them; there are other safety countermeasures that are effective for pupils outside the bus.

The effectiveness of seat belts in minimizing fatalities depends on many factors, like the speed of the bus and other involved vehicles, the size of other involved vehicles, the type of crash, and the bus point of impact. The effectiveness of the belts is conditional these factors. It would take an extremely large amount of data to establish the exact effect of each factor, but such data are not available.

4.3.1 Rare Events

It is difficult to establish the nature of fatalities in school bus crashes due to their infrequent occurrence. Nationally, there are about 20 school bus fatalities annually, but three quarters occur outside the bus during pupil loading or unloading, so there is an average of about five pupil fatalities inside school buses annually. They are rare events and too infrequent for a statistical analysis for a given year. But grouping several years of data allows a more thorough investigation from which trends may be noted and conclusions drawn. For example, the two NHTSA school bus fatality studies (2002, 2006) cited in the literature review accumulated 11 years of data each.

The introduction to this research report indicated that there were only 2 fatal school bus crashes in Alabama in 34 years. There are no statistical techniques to analyze such infrequent occurrences without having an unacceptably large error range. The best possible way to analyze Alabama fatalities is to use national data as a proxy, and if possible, to draw inferences about how Alabama data are similar or dissimilar to national data. Proxy values and other accepted techniques must be used to produce reasonable results.

4.3.2 Alabama versus National School Bus Crash Data

At the state level, there is an abundance of general information on traffic crashes. The University of Alabama Center for Advanced Public Safety (CAPS) is capable of extracting these data; performing various analyses on it, including data mining and statistical testing; and preparing reports. There are enough bus crashes in these data for analysis of crashes and the associated injuries. However, there have been insufficient fatal bus crashes for an analysis of fatalities. On the national level, NHTSA has conducted three analyses of fatal school bus-crash data (2002, 2006, and 2008). The 2008 NHTSA report was prepared as part of the federal rule-making process, and it includes analysis of fatalities and injuries. Taken together, these three NHTSA reports give good information about the national school bus fatalities. The following crash data are available:

> Alabama: sufficient injury data but little fatality data
> National: sufficient injury data and sufficient fatality data

It is desirable to use Alabama fatal crash data because it might deviate from national data, but the necessary data are lacking. The best that can be done is to use national fatality data to establish the primary factors associated with fatal and injury crashes and to determine how effective the belts are at making those types of crashes less severe. Where data are available to draw inferences about the difference in national and Alabama fatal crashes, they might be used to adjust the national findings to fit Alabama.

4.3.3 Severity of Injury

The numbers and types of injuries, including fatalities, are key pieces of data in this cost-effectiveness study. Fortunately good injury data are available for Alabama school bus crashes. The researchers at CAPS extracted 10 years of pupil injuries, including fatalities, from Alabama crash data. The data, collected by law-enforcement officers using the KABCO crash-injury scale, are displayed in Table 4-2.

KABCO is one of two commonly used scales. It has six classifications for injury severity. It is common in police crash reports because persons without medical training can use it to make injury assessments without a hands-on examination. However, KABCO ratings are often imprecise and inconsistent.

The second type of injury descriptor is the Maximum Abbreviated Injury Scale (MAIS) developed by the Association for the Advancement of Automotive Medicine. It ranges from 0 (no injury) to 6 (killed). Medical training is required to administer the scale. The MAIS scale is used for this cost-effectiveness study because it allows analysis of the economic cost of crashes by injury severity. The scale includes elements of economic loss such as medical costs and lost productivity, which depend on injury outcome.

Table 4-2. Pupils injured in Alabama school bus crashes (1999-2008)

Year	K killed	A visible or carried from scene	B bruise or abrasion or swelling	C minor pain or faint	O not injured	Total
1999	0	80	13	60	319	472
2000	0	53	9	14	290	366
2001	0	17	2	26	251	296
2002	0	36	4	42	235	317
2003	0	23	5	38	304	370
2004	0	15	1	37	288	341
2005	0	44	1	45	292	382
2006	4	82	10	23	306	425
2007	0	19	17	30	319	385
2008	0	33	4	39	231	307
Total	4	402	66	354	2835	3661
% all crashes	0.1%	11.0%	1.8%	9.7%	77.4%	100.0%
Average	0.4	40.2	6.6	35.4	283.5	366.1

Willke, et al. (1999) developed a technique to convert KABCO values to the MAIS injury scale. A copy of the Willke transformation equation is in the technical appendix.

Using the average year of Alabama school bus injury data from Table 4-2, the Willke transformation equation was applied to convert the data to MAIS injuries. The results are in Table 4-3.

Table 4-3. Alabama school bus crash injuries converted to the MAIS scale

MAIS Injury Level	KABCO Injuries					Fatal	Total MAIS Injuries
	A	B	C	O	U		
0	0.609	0.326	7.051	262.019	0.000	0.000	270.006
1	19.772	5.229	25.392	20.815	0.000	0.000	71.207
2	11.224	0.824	2.393	0.584	0.000	0.000	15.025
3	6.719	0.199	0.534	0.082	0.000	0.000	7.534
4	1.169	0.018	0.023	0.003	0.000	0.000	1.212
5	0.708	0.005	0.006	0.000	0.000	0.000	0.719
Total Injuries	40.200	6.600	35.400	283.503	0.000	0.400	366.103
Fatal	0.000	0.000	0.000	0.000	0.000	0.400	0.4

This study also needs the number and type of fatal crashes that occur annually. NHTSA (2002, 2006, 2008) studies acquired this type of information for fatal crashes by accumulating several years of data. For this study, the most appropriate was NHTSA (2008) prepared to support federal rule-making on school bus safety. NHTSA (2008) included 10 years of data on fatal crash events (for example, rollover) and found 35% of crashes involved rollovers and 29% involved roadway crashes. Together rollovers and roadway crashes accounted for almost two-thirds of all fatal school bus crashes.

The bus point of impact (NHTSA 2008) is in Table 4-4. This is helpful because the effectiveness of seat belts depends on the direction of impact. For example, seat belts are considerably more effective in a front-end impact than a side impact. Thus seat belt effectiveness varies with point of impact. Rear impacts and non-collisions constitute 16% of the data in the table and are not improved by seat belts. In this analysis, seat belt-safety effectiveness is limited to the remaining 84% of fatalities.

These data are also useful for comparison to Alabama school bus-crash data because impact locations are routinely collected for Alabama school bus crashes. No strong differences were found between Alabama and national fatal school bus crashes.

Table 4-4. National pupil fatalities in school buses by principal impact point (1996-2005)

Point of Impact	Crashes (Large School Buses)		
	Total	Per Year	%
Front	13	1.3	25%
Side	12	1.2	24%
Rear	3	0.3	6%
Rollover	18	1.8	35%
Non-collision	5	0.5	10%
Total	51		100%
Average/Year	5.1		

Source: extracted from Table IV-3 of NHTSA (2008)

4.4 Summary

This section discussed the data needed to calculate the cost effectiveness of school bus seat belts. The costs associated with seat belt installation and school bus-crash/injury/fatality data are the two most important pieces of information for this study.

Cost data were provided by the Alabama State Department of Education. They are presented in Table 4-1. School bus-crash injury data were gathered from Alabama records and were converted from the KABCO scale to the MAIS scale so economic values could be associated with crash severity. The data are shown in Table 4-3. Table 4-4 shows fatal school bus-crash data taken from NHTSA (2008) that provided a point-of-impact summary for fatal crashes.

Other necessary data include the average life span of an Alabama school bus, whether aides are needed on all buses to encourage seat belt use, the seat belt-use rate, and whether additional buses will be needed to offset the loss of capacity due to belt installation. Appropriate data values were identified through a literature review or determined through research. This information is presented during the benefit-cost analysis.

Section 5
Benefits

5.1 Introduction

As discussed previously, the benefits of school bus seat belts were defined as reductions of fatalities and injuries after installation of seat belts. Lacking the necessary Alabama fatality data, this study used national data as a proxy. Sometimes Alabama school bus-injury data lacked key variables or was in the wrong format. This required data transformation or data substitution to build a data set for the cost-effectiveness study. NHTSA (2008) provided guidance in using the proxies, transformations, and substitutions. Certain information is needed for this study:

1) Injury/Severity Data – the number of annual fatalities and injuries in Alabama school bus crashes on the MAIS scale – for this study the number of school bus crash injuries and fatalities are shown in Table 4-3.
2) Data on Types of Crashes – crash types associated with injuries and fatalities, which is needed to determine seat belt effectiveness by crash type. There were too few fatal crashes in Alabama for statistical association with crash type, so the pattern of national fatalities by impact point was used as a proxy (see Table 4-4).
3) Belt Effectiveness – school bus seat belt effectiveness in preventing injuries and fatalities for various crash types. NHTSA (2008) used three school bus impact points:
    a. Front-end collisions – crash dummies were used in sled tests to establish deceleration rates for children's heads, necks, thoraxes, and extremities using the belt and not using the belt. Extremities were omitted from the final analysis because they are not crucial for serious injuries and fatalities. The sled-test deceleration rates were matched to MAIS injury levels to determine the reduction in fatalities and injuries for three types of pupils: an average-size 6-year old, a 5^{th} percentile female (approximate age 10-14), and a 50^{th} percentile male (approximate age 15-19).
    b. Side collisions – there are no test data or school bus-crash data to determine the effectiveness of seat belts in side impacts. NHTSA used a proxy value for side impacts on school buses: the rate for automobiles (21% effective) taken from Kahane (2000).
    c. Rollover collisions –there are no test data or school bus-crash data to estimate the effectiveness of seat belts on school buses from rollover crashes. NHTSA again used the rate for automobiles (74% effective) as a proxy (Kahane 2000).
    d. Rear collisions – NHTSA did not consider rear collisions because school bus compartmentalization offers sufficient protection in rear collisions.

5.2 Preparation of Injury-Severity Data

This research requires a sufficiently large data set of pupil injuries and fatalities reported using the MAIS scale. The injuries must result from front-impact, side-impact, or rollover school bus crashes. Alabama injury and fatality data are available, but not in the correct format.

The first step in data preparation involved partitioning Alabama MAIS injuries by the impact point on the bus. This step used NHTSA's multiplicative factors, which were prepared from data available in the National Automotive Sampling System-General Estimates System (NASS-GES). Table B-2 in the Technical Appendix displays NHTSA's findings for total pupil MAIS injuries and injuries separated by point of impact (front, side, rollover, and rear/other). Table B-2 was used to transform Alabama school bus crash injuries and fatalities to match the NASS-GES pattern. Rear impacts and non-collisions were not included because seat belts do not help them much. The transformed Alabama data are shown in Table 5-1.

Table 5-1. Annual Alabama school bus injuries distributed by MAIS injury level and bus point of impact

MAIS Injury Level	Frontal Impact	Side Impact	Rollover	Total
0	79.08	122.76	0.08	201.92
1	14.22	28.82	0.72	43.76
2	4.10	5.24	0.35	9.69
3	2.06	2.37	0.24	4.67
4	0.26	0.32	0.05	0.63
5	0.18	0.18	0.04	0.40
Level 1 - 5 Injuries	20.82	36.93	1.40	59.15
Fatalities	0.10	0.09	0.14	0.33

MAIS Level 0 indicates no injury

The next step is to redistribute the injuries by age and by location of body injury. This is important for determining the severity of an injury given the magnitude and direction of the crash impact. This information is obtained from an American Academy of Pediatrics (AAP) study (McGeehan, et al. 2006). Table 2-2 provides the AAP tabulation of child school bus injuries by age group and Table 2-3 by body part. NHTSA (2008) used these tables to produce a table of MAIS injuries by age and body part.

NHTSA (2008) also matched the age groups in Table 2-3 with the ages represented by crash dummies. The six-year-old dummy represented the 0-4 and 5-9 age groups. The 10-14 age group was represented by the 5th percentile female dummy, and the 15-19 age group was represented by the 50th percentile male. Tables C-3 and C-4 in the appendix display the final NHTSA redistributed injuries by MAIS scale value, dummy type (that is, age), and injury location. Because injuries to extremities do not contribute significantly to severe injuries, NHTSA did not partition the data by age and body part for MAIS categories 0 to 3. Alabama data were similarly transformed; the results are shown in Table 5-2.

5.3 Benefits in Front-End Impacts

NHTSA conducted a series of sled crashes using dummies representing a 6 year old, a 5th percentile female child, and a 50th percentile male child. The sleds were crashed into a concrete barrier at 30 miles per hour with belted and unbelted dummies. Impact stresses were recorded for various body locations for all crashes and were analyzed for the probable level of MAIS injury inflicted on a real child. By comparing the injury/fatality results estimated for belted pupils to unbelted pupils, the effectiveness of seat belts was established for preventing injuries/fatalities for various ages and body locations.

Table 5-2. Distribution of Alabama injuries by dummy type, body region, and severity

Dummy Type	Injury Location	No Injuries	MAIS 1	MAIS 2	MAIS 3	MAIS 4	MAIS 5	Injury total	Fatal
6 year old	Head	7.34	1.32	0.38	0.19	0.04	0.03	9.29	0.02
	Neck	3.53	0.63	0.18	0.09	0.03	0.02	4.48	0.01
	Thorax	4.16	0.75	0.22	0.11	0.03	0.02	5.28	0.01
5th percentile female	Head	10.05	1.81	0.52	0.26	0.06	0.04	12.73	0.02
	Neck	4.83	0.87	0.25	0.13	0.03	0.02	6.14	0.01
	Thorax	5.70	1.03	0.30	0.15	0.04	0.02	7.23	0.01
50th percentile male	Head	5.98	1.08	0.31	0.16	0.03	0.02	7.58	0.01
	Neck	2.88	0.52	0.15	0.07	0.02	0.01	3.65	0.01
	Thorax	3.40	0.61	0.18	0.09	0.02	0.01	4.31	0.01
Totals		47.86	8.60	2.48	1.24	0.29	0.20	60.69	0.11

Table B-5 provides estimated injuries for standard-height seat backs and lap belts, and it provides estimated injuries high seat backs plus lap/shoulder belts. Comparing the two estimates provides effectiveness of moving from lap belts to lap/shoulder belts. Although this particular NHTSA comparison is not applicable to the Alabama Pilot Project, it does illustrate the NHTSA process of estimating the effectiveness of seat belts.

There is a second important point to the table. Some of the cells in the table contain negative effectiveness values (reduce the injuries and fatalities associated with this type of crash) and some contain positive values (increase the injuries and fatalities associated with this type of crash). This is because a prevented fatality may be an injury or a serious injury might become a minor injury. Ideally, the number of crashes in each cell of the table would be reduced and passed to a lower severity. Thus the fatality and serious-injury categories might go down while the minor-injury and no-injury categories might increase.

The NHTSA 2008 effectiveness estimates were applied to front-end crashes of Alabama school buses to generate the number of lives saved and injuries reduced by the implementation of seat belts. The results are shown in Table 5-3.

Table 5-3. Summary of Alabama benefits for front-end impacts

Dummy Type	Benefits	No Injury Reduction	AIS 1 Reduction	AIS 2 Reduction	AIS 3 Reduction	AIS 4 Reduction	AIS 5 Reduction	Fatal Reduction
6 yr-old dummy	Head Injury	-1.40	0.79	0.36	0.19	0.04	0.03	0.015
	Neck Injury	-0.32	0.21	0.06	0.03	0.01	0.01	0.005
	Chest Injury	-0.22	0.11	0.03	0.06	0.02	0.01	0.006
	Sub-total	-1.95	1.10	0.46	0.28	0.07	0.05	0.027
5th % female dummy	Head Injury	-0.75	-0.10	0.50	0.26	0.05	0.04	0.021
	Neck Injury	-0.21	0.00	0.00	0.13	0.05	0.03	0.010
	Chest Injury	-0.23	0.11	0.03	0.05	0.02	0.01	0.006
	Sub-total	-1.18	0.02	0.53	0.44	0.12	0.08	0.038
50th percentile male dummy	Head Injury	-0.46	-0.01	0.27	0.14	0.03	0.02	0.012
	Neck Injury	0.13	-0.18	-0.05	0.07	0.01	0.01	0.005
	Chest Injury	-0.11	0.06	0.02	0.02	0.01	0.00	0.002
	Sub-total	-0.44	-0.13	0.24	0.24	0.05	0.04	0.020
Total Benefits		**-3.57**	**0.99**	**1.22**	**0.95**	**0.24**	**0.17**	**0.08**

5.4 Total Benefits and Benefits in Side Impacts and Rollovers

The calculation of benefits from school bus seat belt implementation is simpler for side impacts and rollover crashes than for front-end crashes. NHTSA (2008) handled this type of crash using proxy values, adopting effectiveness rates for automobiles from Kahane (2000). For side impacts the effectiveness is 21%, and for rollovers the effectiveness is 74%. These values were applied to the tabulated crashes by injury level from Table 5-1. The results are shown in Table 5-4. The benefits from front-end crashes were added to the table to produce the total reductions of injuries and fatalities if seat belt use were 100%. However, because the Alabama Pilot Project found belt use averaged 61.5% (Tedla, et al. 2010), the benefits were reduced accordingly.

Seat belts cannot prevent all fatalities in a school bus crash, but they can prevent some and convert many of the remaining fatalities into injuries. For this study, Table 5-5 displays the effectiveness of seat belts in preventing fatalities and reducing injuries for the three impact points evaluated in the study.

The table shows estimates the belts will reduce fatalities by 39% and overall injuries by 13% for pupils on school buses. The largest reduction is for the most severe crashes (MAIS 4 and 5): 63% of severe injuries become less severe with school bus seat belts.

5.5 Estimated Costs of Injuries and Fatalities

NHTSA (2002) presented a methodology to estimate the value of a statistical life and has periodically refined the method. It associates costs for medical care, insurance, lost market productivity, legal expenses, property damage, and other factors with MAIS injuries and fatalities. Table 5-6 displays the NHTSA (2008) values.

For a simplistic estimate of the benefits school bus seat belts would accrue, multiply the injury subtotals in Table 5-6 by the number of corresponding Alabama injuries and fatalities. The results are shown in Table 5-7. Installing seat belts on every school bus in Alabama could yield an annual average economic benefit of $2,744,521.

Table 5-4. Summary of annual reductions of injuries and fatalities

Injury Levels	Front	Side	Rollover	Totals
For 100% Seat Belt Use				
MAIS 1	0.99	6.05	0.53	7.57
MAIS 2	1.22	1.10	0.26	2.58
MAIS 3	0.95	0.50	0.18	1.63
MAIS 4	0.24	0.07	0.04	0.35
MAIS 5	0.17	0.04	0.03	0.24
Total Injuries	3.57	7.75	1.04	12.36
Fatalities	0.08	0.02	0.10	0.20
For Actual Seat Belt Use (61.5%)				
MAIS 1	0.61	3.72	0.33	4.66
MAIS 2	0.75	0.68	0.16	1.59
MAIS 3	0.59	0.31	0.11	1.00
MAIS 4	0.15	0.04	0.02	0.21
MAIS 5	0.10	0.02	0.02	0.14
Total Injuries	2.20	4.77	0.64	7.60
Fatalities	0.05	0.01	0.06	0.13

Table 5-5. Simple estimate of school bus seat belt effectiveness

Situation	Severity	Front	Side	Rollover	Totals
Without Seat belts	Level 1-5 Injuries	20.82	36.93	1.4	59.15
	Fatalities	0.1	0.09	0.14	0.33
Reduced by Seat belts	Level 1-5 Injuries	2.2	4.77	0.64	7.6
	Fatalities	0.05	0.01	0.06	0.13
Effectiveness (% reduced)	Level 1-5 Injuries	11%	13%	48%	13%
	Fatalities	50%	11%	50%	39%

5.6 Summary

This portion of the research, which calculated the cost effectiveness of installing seat belts on school buses in Alabama, was modeled after NHTSA's (2008) cost-effectiveness calculations. Average values for the previous 10 years of Alabama injury and national fatality data were applied using the national pattern for school bus crashes. These data were then redistributed and transformed into the format used by NHTSA.

Seat belt effectiveness values for front-end crashes were based on NHTSA sled tests that developed crash severity data for crash dummies representing three pupil age groups. Lacking data to develop similar effectiveness estimates for side and rollover crashes, NHTSA used proxy values taken from automobile research.

When the seat belt-effectiveness ratios were applied to the transformed Alabama data, it yielded estimates of 0.13 fatalities and 7.60 injuries reduced per year. The NHTSA Statistical Value of

Life methodology was used to convert the estimates of reductions of fatalities and injuries into an estimated economic benefit of $2,744,521 per year.

Table 5-6. Comprehensive costs and relative value factors reflecting crash avoidance and crashworthiness and the value of a statistical life (VSL)

CPI	Factor	MAIS 1	MAIS 2	MAIS 3	MAIS 4	MAIS 5	Fatal
1.346066	Medical	$3,369	$22114	$65,805	$185,840	$470,532	$31,271
1.204077	EMS	$123	$268	$466	$1,050	$1,079	$1,055
1.277512	Market Productivity	$2,349	$33,604	$95,979	$142,973	$589,284	$799,706
1.277512	Household Productivity	$769	$9,835	$28,309	$37,623	$200,556	$257,285
1.204077	Insurance Administration	$938	$8,747	$23,919	$409,406	$86,338	$46,994
1.277512	Workplace	$339	$2,623	$5,730	$6,311	$11,002	$11,689
1.204077	Legal	$190	$6,307	$20,013	$42,688	$101,100	$129,309
1.277512	Travel Delay	$1,044	$1,137	$1,263	$1,342	$12,299	$12,288
1.204077	Property Damage	$4,866	$5,006	$8,608	$12,449	$11,959	$13,005
1.277512	QALYs*	$9,587	$196,121	$275,678	$825,151	$2,812,228	$5,141,362
New Comprehensive Costs		$23,573	$285,762	$525,771	$1,296,321	$4,296,367	$6,443,964
Injury Subtotal		$17,633	$279,620	$515,900	$1,282,530	$4,272,119	$6,418,670
QALY Relatives		0.0019	0.0381	0.0536	0.1605	0.5470	1.0000
Comprehensive Relatives (Crash Avoidance)		0.0037	0.0443	0.0816	0.2012	0.6667	1.0000
Comprehensive Relatives (Crashworthiness)		0.0028	0.0436	0.0804	0.1998	0.6656	1.0000

*QALY: Quality-Adjusted Life-Years
Source: Table VII-1 (NHTSA 2008). The numbers are adjusted to 2010 dollars using the Consumer Price Index (CPI).

Table 5-7. Calculation of annual economic benefits of school bus seat belts in Alabama

Category	MAIS 1	MAI2 1	MAIS 3	MAIS 4	MAIS 5	Fatalities	Total Benefits
Injury Subtotal Table 5-6	$17,633	$279,620	$515,900	$1,282,530	$4,272,119	$6,418,670	- -
Alabama Injuries	4.66	1.59	1	0.21	0.14	0.13	- -
Economic Benefits	$82,170	$444,596	$515,900	$269,331	$598,097	$834,427	$2,744,521

Section 6
Benefit/Cost Analysis

6.1 Introduction

This section of the report compares identified benefits associated with installation of seat belts on school buses with identified costs of the seat belts to estimate the cost effectiveness of the belts. The benefits were identified at the end of Section 5. The reductions in fatalities and in severity of injuries amount to an estimated gain of $2,744,521 per year.

The costs involve installation of the belts, purchase of new buses to offset the loss of capacity due to the belts, and similar issues. ALSDE obtained 2010 quotes from bus vendors and added historical data from its files to estimate the costs. That information is displayed in Table 4-1 of this report and is summarized below for the convenience of the reader.

$79,890	Average cost of a new school bus
$12,000	3/3 seats with belts at max spacing (cost above existing seats)
$15,000	3/3 seats with belts without max spacing (cost above existing seats)
$11,000	3/2 seats with belts with max spacing (cost above existing seats)
$13,000	3/2 seats with belts without max spacing (cost above existing seats)
$1,000	Extend passenger compartment to the offset loss of a row of seats
$4,867	Operating cost – annual fuel per bus
$3,106	Operating cost – annual maintenance per bus
$26,271	Driver average salary plus benefits
$21,443	Aide average salary plus benefits
0.0%	Annual growth, pupils transported
0.0%	Annual growth, buses purchased
1.1%	Annual growth, bus miles traveled
10 years	Fleet rotation cycle target

6.2 Range of Minimum and Maximum Costs

In performing this analysis, optional ways to install seat belts were identified. These involve the following choices for school systems:

- Decision on whether to use a school bus aide;
- Selection of a school bus manufacturer who includes school bus seat belts;
- Selection of seat/row configuration; and
- Selection of minimum or maximum row spacing (ALSDE prefers maximum spacing).

School districts across the nation have different preferences, funding bases, laws, and guidelines, so it is probable there will be a wide variety of seat belt implementations. That makes it impossible to estimate seat belt cost effectiveness that covers all options across the country, so UTCA researchers provided a range of estimates for the most probable situations.

The cost-effectiveness range was bounded by the following situations:

- Cost includes an aide (two options – yes, no)
- Cost of seat/seat belt by manufacturer (three options)
- Seat/row configuration (four options, including flex seats)
    - Cost of seats varies by configuration
    - Capacity of bus varies by configuration and length of bus

Note that seat/row configurations have two effects on the overall costs. The direct cost is the number of seats purchased and installed (cost of seat belt seats above the cost of conventional seats). The indirect cost is the purchase of additional buses to offset the loss of seats due to seat belt installation. For each configuration, UTCA researchers determined the combination of direct costs for seat purchase plus indirect costs for additional buses (bus purchases, seat purchase, operating costs for fuel and maintenance, and cost of drivers' salaries plus benefits).

Analyses were conducted to determine the direct and indirect costs of each seat configuration and minimum/maximum row spacing. The minimum cost of the analysis of all configurations was taken as the minimum overall cost of implementation of seat belts. The maximum cost from value of the analysis of all configurations, including the costs of aides for existing and new buses, was taken as the maximum overall cost of seat belt implementation of seat belts, including the costs of aides.

6.3 Phasing Seat Belt Installation into the Fleet

It is not cost effective to retrofit seat belts to school buses. The frames of existing buses were not designed to anchor the seats and absorb the shock forces during a crash. It is more efficient to phase in seat belts as new buses are purchased. ALSDE policy calls for bus-fleet rotation over a 10-year period. That is, the target is to replace 10% of the existing fleet with new buses each year.

Each year, the fleet with seat belts should increase 10 percentage points each year. This translates to 10-percentage-point increases in safety benefits and costs annually. At the end of 10 years the full benefits will be obtained and ALSDE budget will have increased enough to sustain the full cost of installing the belts. In other words, the school bus budget will stabilize after 10 years of increases.

Table 6-1 summarizes the costs associated with the 10-year phase-in of the belts. Column 1 of the Table shows five seat belt configurations. In addition to the four discussed previously, a configuration was added for flex seats with an extended passenger compartment to offset the loss of a row of seats due to thicker seat backs. Although such a long passenger compartment is not yet available, at least one manufacturer has indicated a willingness to provide it.

Column 2 shows the year under study. Column 3 shows the additional annual costs seat belts impose through normal fleet rotation, and column 4 shows the costs associated with offsetting loss of capacity due to seat installation. Only the 1st and 10th years are shown to keep the Table from becoming too long, but the intervening years were calculated in the same manner. Note that the fifth configuration (3/3-12 long) does not have any loss of capacity, and thus no cost is shown in column 4.

Column 5 shows the growth in the additional annual costs of providing the belts with and without bus aides. Column 6 shows the cumulative amount spent on installation of belts since the phase-in program began.

Table 6-1. Summary of costs of school bus seat belts by configuration over a 10-year period without consideration of the time value of money

Column 1	2	3	4	5		6	
Configuration	Year	Fleet Rotation (x $1000)	Restore Capacity (x $1000)	Added w/o Aides (x $1000)	Added w/ Aides (x $1000)	Cumulative w/o Aides (x $1000)	Cumulative w/ Aides (x $1000)
3/3-12 Flex[1,2]	1st	$11,025	$759	$12,058	$27,990	$12,058	$27,990
	⋮	⋮	⋮	⋮	⋮	⋮	⋮
	10th	$11,025	$759	$14,524	$182,916	$132,909	$1,055,300
3/3-11[3]	1st	$8,820	$9,465	$21,812	$39,781	$21,812	$39,781
	⋮	⋮	⋮	⋮	⋮	⋮	⋮
	10th	$8,820	$9,465	$53,566	$223,985	$376,839	$1,319,601
3/2-12[2,4]	1st	$9,555	$3,437	$14,259	$30,813	$14,259	$30,813
	⋮	⋮	⋮	⋮	⋮	⋮	⋮
	10th	$9,555	$3,437	$25,662	$194,676	$199,606	$1,128,216
3/2-11[5]	1st	$8,085	$12,088	$24,728	$43,340	$24,728	$43,340
	⋮	⋮	⋮	⋮	⋮	⋮	⋮
	10th	$8,085	$12,088	$65,718	$236,790	$452,228	$1,401,424
3/3-12 Long[6]	1st	$11,025	$0	$11,025	$0	$11,025	$0
	⋮	⋮	⋮	⋮	⋮	⋮	⋮
	10th	$11,759	$0	$11,759	$0	$117,590	$1,030,926

[1]Standard-length bus, flex seats at minimal spacing

[2]Minimal spacing of seats does not meet ALSDE spacing criteria

[3]Standard-length bus, flex seats at maximum spacing, loss of one row of seats due to seat back thickness

[4]Standard-length bus, standard seats at minimal spacing

[5]Standard-length bus, standard seats at maximum spacing

[6]Extended-length bus to accommodate flex seat with maximum spacing, no loss of a row due to seat back thickness

There are two things of note in Table 6-1. First, the configurations with the least and greatest costs are identified. The lowest-cost configuration is 3/3-12 long without aides, and the highest-cost configuration is 3/2-11 with aides. These are understandable. Second, the table includes a cost estimate for installing seat belts for each configuration.

Tables 6-2 and 6-3 provide more specific examples. They contain details of the phase-in for the 3/2-11 and the 3/3-12 long configurations (the most costly and least costly options, respectively). Notice that after 10 years the entire fleet has been replaced with seat belt-equipped buses and enough additional buses have been purchased to replace lost capacity due to seat belt implementation. At this point the annual budget expansion ceases and the system stabilizes.

Table 6-2. Costs and benefits over the 10-year phase-in for 3/2-11 configuration, without consideration for the time value of money

Year	Fleet Rotation (x $1000)	Restore Capacity (x $1000)	Added w/o Aides (x $1000)	Added w/ Aides (x $1000)	Cumulative w/o Aides (x $1000)	Cumulative w/ Aides (x $1000)
2009	$0	$0	$0	$0	$0	$0
2010	$8,085	$12,088	$24,728	$43,340	$24,728	$43,340
2011	$8,085	$12,088	$29,282	$64,856	$54,010	$108,197
2012	$8,085	$12,088	$33,837	$86,372	$87,847	$194,569
2013	$8,085	$12,088	$38,391	$107,888	$126,238	$302,457
2014	$8,085	$12,088	$42,946	$129,404	$169,184	$431,860
2015	$8,085	$12,088	$47,500	$150,919	$216,684	$582,780
2016	$8,085	$12,088	$52,055	$172,436	$268,738	$755,216
2017	$8,085	$12,088	$56,609	$193,951	$325,347	$949,167
2018	$8,085	$12,088	$61,163	$215,467	$386,511	$1,164,634
2019	$8,085	$12,088	$65,718	$236,790	$452,229	$1,401,424
2020	$20,173	$0	$65,718	$236,790		
2021	$20,173	$0	$65,718	$236,790		
2022	$20,173	$0	$65,718	$236,790		
2023	$20,173	$0	$65,718	$236,790		

Table 6-3. Costs and benefits over the 10-year phase-in for a 3/2-12 long configuration, without consideration of the time value of money

Year	Fleet Rotation (x $1000)	Restore Capacity (x $1000)	Added w/o Aides (x $1000)	Added w/ Aides (x $1000)	Cumulative w/o Aides (x $1000)	Cumulative w/ Aides (x $1000)
2009	$0	$0	$0	$0	$0	$0
2010	$11,759760	$0	$11,759760	$27,520521	$11,759760	$27,520521
2011	$11,759760	$0	$11,759760	$45,21544,482	$23,518520	$72,735003
2012	$11,759760	$0	$11,759760	$62,91061,443	$35,277280	$135,645133,446
2013	$11,759760	$0	$11,759760	$80,60678,405	$47,036040	$216,251211,851
2014	$11,759760	$0	$11,759760	$99,03595,366	$58,795800	$315,286307,217
2015	$11,759760	$0	$11,759760	$115,997112,328	$70,554560	$431,283419,545
2016	$11,759760	$0	$11,759760	$133,692129,289	$82,313320	$564,975548,834
2017	$11,759760	$0	$11,759760	$151,387146,250	$94,072080	$716,362695,084
2018	$11,759760	$0	$11,759760	$169,083163,212	$105,831840	$885,445858,296
2019	$11,759760	$0	$11,759760	$186,585179,980	$117,590600	$1,072,030038,277
2020	$11,759760	$0	$11,759760	$186,585179,980	$129,360	$1,218,257
2021	$11,759760	$0	$11,759760	$186,585179,980	$141,120	$1,398,237
2022	$11,759760	$0	$11,759760	$186,585179,980	$152,880	$1,578,218
2022	$11,759760	$0	$11,759760	$186,585179,980	$164,640	$1,758,198

For the most costly option, 3/2-11 with aides, the cumulative additional cost over the phase-in period is $1.4 billion, and after 10 years the additional cost stabilizes at $236,790,000 for each additional year. The majority of these expenses are associated with personnel costs (drivers for buses to restore capacity and aides for the existing fleet and for the buses to restore capacity).

For the least costly option – 3/3-12 long without aides – the cumulative additional cost over the phase-in period is $117,600,000 and $$11,760,000 a year after that. This is the cost of installing flex seats (max spacing) plus the cost of extending the passenger compartment to offset the loss of a row of seats due to thicker seat backs.

6.4 Two NHTSA Cost-Effectiveness Metrics

The Office of Management and Budget (OMB) requires federal agencies to perform cost-effectiveness analyses to support proposed rule-making to "learn if the benefits of an action are likely to justify the costs or to discover which of various possible alternatives would be the most cost-effective" (OMB 2004). A cost-effectiveness analysis is required of federal agencies conducting a regulatory analysis under Section 6(a)(3)(c) of Executive Order 12866, "Regulatory Planning and Review."

For its rule-making, NHTSA (2008) conducts two types of analyses: "a cost-effectiveness estimate that measures the cost per equivalent life saved [and a] benefit-cost estimate [that] measures the net benefit, which is the difference between benefits and net costs in monetary values." Because future values of benefits are included in the analysis, they are discounted. NHTSA does this using a range of discount rates. The following pages of the report develops these estimates for seat belts on full-size buses in Alabama using NHTSA methodology and the data and findings previously discussed in this report.

6.5 Cost Effectiveness

The determination of the cost per equivalent life saved is based on comprehensive values and is composed of economic impact and lost quality of life. Typically this includes the costs of factors like medical care, emergency medical services, legal services, insurance, and lost productivity.

The comprehensive costs used by NHTSA (2008) to evaluate the safety effectiveness of several proposed school bus regulations were updated by UA researchers to reflect 2010 dollars using the Consumer Price Index. This information is displayed in Table 5-6.

The cost per equivalent life saved recognizes reductions in fatal and non-fatal injuries, where non-fatal injuries are expressed in terms of fatalities. This is accomplished by calculating ratios (called "relatives") for each MAIS injury level by comparing the cost of preventing the MAIS injury to the cost of preventing a fatality (NHTSA 2001). These ratios are shown in the "Comprehensive Relatives (Crashworthiness)" line of Table 5-6.

The Relative value for each injury level is multiplied by the appropriate number of injuries to produce the number of equivalent lives saved for each MAIS injury level. This process is shown in Table 6-4, and the resulting undiscounted value of equivalent lives saved is 0.427 per year. Because the analysis covers the life cycle of a bus (10 years in Alabama), the value is expressed as 4.27 equivalent lives.

Table 6-4 Calculation of Alabama equivalent lives saved

	MAIS 1	MAIS 2	MAIS 3	MAIS 4	MAIS 5	Fatal	Equiv Lives per Year
Number Injuries	4.66	1.59	1.00	0.22	0.15	0.12	
Relative*	0.0028	0.0436	0.0804	0.1998	0.6656	1.0000	
Equiv Fatalities	0.013	0.069	0.081	0.043	0.098	0.123	0.427

*Comprehensive "relative" for crashworthiness (ratio: number of MAIS "x" injuries/ fatalities), Table 5-6

A measure of future crash opportunity is needed to calculate discounted future benefits. School buses are exposed to possible crashes when they are on the road, so one measure of exposure is miles driven annually. In the 2009-2010 academic year, the average Alabama school bus traveled 11,212 miles (ALSDE 2010a). The miles driven per bus increased 1.1% per year (see Table 4-1).

The 2009-10 mileage was extended into the future at a 1.1% annual growth rate in Table 6-5. By applying standard 3% and 7% discount rates (NHTSA 2008), the discounted value of mileage was determined to be 0.8636 and 0.7725 respectively. In Table 6-6, these values were applied to future benefits (fatalities and injuries prevented) to determine the discounted cost per equivalent life saved as $32 million to $38 million.

Table 6-5 Discount rates based on school bus mileage in Alabama

Year	Mileage	3% rate	7% rate
2010	11,212	0.9853	0.9667
2011	11,324	0.9566	0.9035
2012	11,437	0.9288	0.8444
2013	11,552	0.9017	0.7891
2014	11,667	0.8755	0.7375
2015	11,784	0.8500	0.6893
2016	11,902	0.8252	0.6442
2017	12,021	0.8012	0.6020
2018	12,141	0.7778	0.5626
2019	12,262	0.7552	0.5258
Sum =	117,301		
% original mileage =		0.8636	0.7225

Table 6-6 Cost per equivalent life saved over a 10-year fleet rotation

Discount Rate	Discount Factor	Equiv. Lives	Discounted Equiv Lives	Belt costs ($M)	Cost per Equiv Life Saved
3%	0.8626	4.27	3.69	117.59	$32 million
7%	0.7225	4.27	3.09	117.59	$38 million

6.6 Net Benefits

NHTSA calculates net benefits as the monetary difference between benefits and costs. Because it deals with future benefits, it is discounted in the same manner as the calculation of the cost of an equivalent life saved except two differences. First, seat belts affect the crashworthiness of the bus; they do not affect property damage or vehicle delay. So unlike the calculation of the cost to save an equivalent life, comprehensive crash costs are not used. Injury costs (see "Injury Subtotal" line of Table 5-6) are used instead because they exclude property damage and vehicle delay. The "injury" value of $6,418,670 for a fatality was used for calculations in this report.

Second, net benefits are calculated for only the least expensive seat/row arrangement, the 3/3-12 long configuration, without aides. It provides the most favorable estimates for seat belts – other configurations have lower net benefits.

NHTSA determines total present benefits by multiplying the value of a statistical life by the equivalent lives saved: 4.27 equivalent lives multiplied by $6,418,670. The costs of installing the seat belts over the ten-year replacement cycle for Alabama school buses has been previously documented in Table 6-3 as $117.59 million. These values are used in Table 6-7 to determine the range of discounted net benefits as $-104 million to $-125 million.

Table 6-7 Net benefits ($ million) for a 3/3-12 long configuration

Total Costs	$117.6
Benefits	$27.4
Net Benefits Current	$-90
Net Benefits @ 3%	$-104
Net Benefits @ 7%	$-125

Because the costs exceed the benefits, the net benefits have negative values. One reason the values are large because only five pupils inside school buses have been killed in crashes since 1976, when school bus compartmentalization was first required. Another reason is seat belts cannot save all lives in a crash. This research estimated that, on average, they could have reduced Alabama pupil fatalities by 39%, not 100%.

6.7 Alternative Safety Treatments

The decision to install school bus seat belts is the prerogative of individual school districts and individual schools. But given the relatively high costs of the belts compared to their safety benefits, and that the lives of relatively few pupils would be saved each year, it seems prudent to investigate other treatments that might be more cost effective at reducing the number of fatalities and injuries. This finding is consistent with the literature:

- The National Transportation Safety Board (1987) indicated that "the overall benefits of requiring seat belts on large school buses are insufficient to justify a federal requirement for mandatory installation" and "the funds used to purchase and maintain seat belts might be better spent on other school bus safety programs and devices that could save more lives and reduce more injuries."

- NHTSA (2008) stated that, "if every child in every large school bus wore their lap/shoulder belt, 2 lives per year could be saved." With 100% of the pupils nationwide belted, only about two lives would be saved each year. At this rate, it would take many years to save a single life in Alabama on average.
  The same report underscored that school buses are the safest form of highway transportation: "It would only take one-quarter of 1% percent of school children to be diverted (from school buses) to other means of transportation for those fatalities to rise by 2 children." If seat belts are not accepted by students of their parents, the safety gained by the belts could be negated by a small percentage of pupils transferring to other types of vehicles.
- The TRB special report on school bus transportation (National Academies 2002) found 75% of national fatalities in school bus crashes were pedestrian children. Children are more at risk while entering or exiting school buses than while they are traveling inside the buses.
- NHTSA (2002) found 58% of pupil fatalities in school bus crashes were pedestrians. Two-thirds involved the school bus itself and the rest involved motorists illegally passing a stopped school bus.
- NHTSA (2006) came to a similar conclusion: "Children are at greater risk of being killed in school bus loading zones (that is, boarding and leaving the bus) than inside the bus, so it seems logical that a larger share of the school bus safety effort should be directed to improving the safety of school bus loading zones."
- NHTSA (2006) found "pedestrian fatalities account for the highest number of school bus-related fatalities. There are about 17 such fatalities per year, two-thirds of which involve the school bus itself and the rest involve motorists illegally passing the stopped school bus."

This brief review indicates seat belts have a minimal impact on pupil fatalities. The UA study did not find any data and did not draw any conclusions that would dispute or refute these statements. In other words, nothing was identified that supported the mandatory use of seat belts.

6.7.1 Suggested Alternative Safety Treatments

The literature indicates improving the loading and unloading zone around school buses could be a more cost-effective treatment than seat belts, and Alabama data confirm.

ALSDE annually compiles records of all school bus crashes and some contributing factors. These records show that during the past decade six pupils were killed in crashes in school bus loading and unloading zones. Like the national pattern, there were more Alabama pupil fatalities outside than inside school buses. The Alabama fatalities were three to nine years old. Two of the fatalities involved school buses and four involved other vehicles.

ALSDE asks school systems to tabulate instances of vehicles illegally passing school buses that are stopped to load or unload school buses. In 2009-2010, the systems reported 1633 instances of vehicles failing to stop, including some that passed on the right side of the school bus.

In summary, ALSDE records indicate that Alabama reflects the national pattern. Most pupil school bus fatalities occur outside the bus in or near loading zones. So if funding is to be spent on school bus safety, more lives could be saved by investing in enhanced safety measures in loading/unloading zones through education, training, and greater enforcement efforts of the "no passing a school bus loading students" law. Examples of such programs include:

- Enhanced school bus safety technology applicable to loading and unloading pupils;
- Additional driver training;
- Additional education/training to students and teachers;
- Additional training of crossing guards;
- Upgraded traffic control at school crossings;
- Public education about passing a school bus that is loading/unloading pupils;
- Enforcement efforts by the Department of Public Safety, local police agencies, and school districts; and
- Analysis of school loading areas for difficult bus maneuvers, mixing vehicles and child pedestrians in the same traffic streams, and other potential contributors to pedestrian crashes.

6.8 Summary of Cost Effectiveness

In summary, UA researchers conducted a thorough cost-effectiveness study of school bus seat belt use in Alabama using NHTSA procedures and had several findings:

1) The most cost-effective configuration for installation of seat belts is 3/3-12 long. The least cost-effective configuration for installation of seat belts is 3/2-11.
2) Costs far exceed benefits, and school bus seat belts are not as cost effective as other types of safety treatments.

- The cost of an equivalent life saved from seat belt implementation is $32 million to $38 million.
- The net benefits from seat belt implementation over one cycle of fleet life (10 years) are negative, ranging from -$104 million to - $125 million.
- The most cost-effective configuration for installation of seat belts is 3/3-12 long. The least cost-effective configuration for installation of seat belts is 3/2-11.
- Costs far exceed benefits, and school bus seat belts are not as cost-effective as other types of safety treatments.

Section 7
Summary, Conclusions, and Recommendations

This report presents a cost-effectiveness analysis of school bus seat belt implementation in Alabama. The study was patterned after NHTSA's (2008) methodology developed for a regulatory analysis of potential school bus safety enhancements.

The report includes a brief overview of school bus safety. School buses are the safest vehicles on the road. NHTSA (2006) indicates "school buses are approximately seven times safer than passenger cars or light trucks." In recent years Alabama school buses have averaged 560 traffic crashes per year while driving a high number of miles (83 million route miles in 2009-2010). The rate of school bus crashes per mile driven is well below that of other vehicles in the state. Also, school buses have many fewer fatal crashes than other Alabama vehicles. Since 1976, when NHTSA required school buses to be compartmentalized for safety, traffic crashes have caused only five fatalities to pupils inside Alabama school buses.

Several noteworthy organizations and agencies provided information useful to framing the key issues. This included two studies by the Transportation Research Board (1989 and 2002), one by the American Academy of Pediatrics (2006), and three by NHTSA (2002, 2006 and 2008). A study by Turner, et al. (2005) of school bus crashes in Alabama provided a starting point for the cost-effectiveness study, and UA researchers prepared a series of reports during the pilot project on seat belt-use rates (Tedla, et al. 2010), differences in national and Alabama fatal school bus crashes (Brown and Turner 2009), and loss of school bus capacity due to seat belt installation (Gurupackiam, et al. 2010).

Cost data for the analysis was provided by ALSDE. This included maintenance and operation costs from its files and price quotes from vendors for purchasing school buses under four different seating configurations. In addition, a variant of the flex-seating configuration was examined using maximum seat spacing and an extended passenger compartment to offset loss of a row of seats due to thicker seat backs.

School bus seat belts produce benefits by saving lives and reducing injuries. However, the appropriate data were difficult to obtain. There were sufficient school bus-crash-injury data, but there too few fatalities for statistical analysis. UA researchers adopted the national school bus fatal crash pattern as a proxy for Alabama. Using NHTSA's methodology, the crash data were converted to the MAIS injury scale so the costs of treatment/prevention could be calculated. Then the injury and fatality data were transformed to represent pupil age groups on Alabama school buses for points of impact (front end and side) and crash types (rollover) for which seat belts are effective.

The study estimated injury and fatality reductions assuming 100% seat belt use on all buses. However, UA researchers conducted over 125,000 observations of individual pupils inside school buses and established an average seat belt use rate of 61.5%, so they reduced projected injuries and fatalities at 61.5% the initially calculated values. Overall, the analysis estimated seat belts will reduce fatalities by 39% and injuries by 13%, resulting in 0.13 fatalities and 7.60 injuries prevented per year.

OMB (2004) requires all federal agencies to perform cost-effectiveness analyses to support proposed rule-making. For its rule-making, NHTSA (2008) conducts two types of analyses: "a cost-effectiveness estimate that measures the cost per equivalent life saved [and a] benefit-cost estimate [that] measures the net benefit, which is the difference between benefits and net costs in monetary values." Because future values of benefits are included in the analysis, they are discounted using a reasonable range of discount rates. NHTSA assigns comprehensive costs to injuries and fatalities and calculates relative-value factors that reflect crash avoidance and crashworthiness to yield an economic "Value of a Statistical Life" (VSL). This is a well-documented procedure (NHTSA 2008).

Using NHTSA's methodology and VSL, along with the costs and benefits documented earlier in this report, UA researchers reached the following conclusions about the implementation of the least-expensive configuration of seat belts in Alabama:

- The cost of an equivalent life saved from seat belt implementation is $32 million to $38 million.
- The net benefits from seat belt implementation over one cycle of fleet life range from $-104 million to -$125 million. The benefits are negative because costs are larger than benefits.
- Costs far exceed benefits, and school bus seat belts are not as cost effective as other types of safety treatments.
- The most cost-effective configuration for installation of seat belts is 3/3-12 long. The least cost-effective configuration for installation of seat belts is 3/2-11.

7.1 Alternative Safety Treatments

The literature indicates there are more pupil fatalities in loading/unloading zones than inside school buses. Alabama crash data follow the same fatality pattern. In addition, ALSDE has collected records for the past decade that demonstrate many vehicles pass school buses that are stopped to load or unload. In 2009-2010 there were 1633 vehicles that did, even though state law requires them to stop during school bus loading/unloading.

Most school bus pupil fatalities occur outside school buses in or near loading zones. If funding is to be spent on school bus safety, it appears more lives could be saved investing in enhanced safety measures in loading/unloading zones rather than in installation of seat belts. These treatments are less expensive than seat belts. Examples of such treatments include the following:

- School bus safety technology applicable to loading and unloading pupils.
- Additional driver training.
- Additional education/training to students and teachers.
- Additional training of crossing guards.

- Upgraded traffic control at school crossings.
- Public education about passing a school bus that is loading/unloading pupils.
- Enforcement efforts by the Department of Public Safety, local police agencies, and school districts.
- Analysis of school loading areas for difficult bus maneuvers, mixing vehicles and child pedestrians in the same traffic streams, and other potential contributors to pedestrian crashes.

Section 8
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Appendix A
Detailed Outline of Cost-Effectiveness Methodology

1) Define the specific goal(s) of the study.
2) Identify potential benefits, costs, and the data needed to conduct the study.
3) Determine if data are available and in the appropriate format (crash, fatality, and injury statistics on the MAIS scale).
   a) What data are available?
   b) Are they appropriate and accurate? If not, can they be transformed? Identify and list possible transformations.
   c) Relate the data to bus crash causal factors (that is, relate Alabama causal factors to national causal factors).
   d) Transform the data to MAIS scale.
4) Determine the effectiveness of available countermeasures.
   a) Compartmentalization
      i) Assess compartmentalization vs. non-compartmentalization.
      ii) Determine how much safer school buses are than other vehicles.
   b) Seat belts as a countermeasure
      i) No field data collected
      ii) Use proxy methods
         (1) Front-end crashes – sled tests related to crash severity
         (2) Side crashes – automobile seat belt factors
         (3) Rollover crashes – automobile seat belt factors
         (4) Rear crashes – crash situation not improved by seat belts
5) Apply safety-effectiveness ratios of countermeasures to determine potential lives saved and injuries prevented.
   a) Front end
      i) NHTSA sled tests
      ii) Automobile rates
   b) Side – Automobile rates as proxies
   c) Rear – unknown
   d) Rollover – unknown
6) Document cost of implementation
   a) Cost of seats
      i) Differential cost of seats
   b) Cost of new buses to make up for lost capacity due to seat belt installation
      i) Capital costs: bus + belts
      ii) Labor (driver/aide)
      iii) Operations
         (1) Fuel
         (2) Non-fuel
         (3) Insurance

iv) Additional time on route (not used for this study)

7) Determine Benefits – NHTSA Value of a Statistical Life
   a) Update to 2010 dollars
8) Cost-Benefit Determination
   a) Variations for discount rates
   b) Variations for types of seat/seat belt
   c) Variations for with aide/without aide
   d) Other
9) Allocation of safety funding for school bus safety
   a) Seat belts if appropriate and cost effective
   b) Alternative suggestions
   c) Cite suggestions in NHTSA report (2008)
   d) School transportation officials' suggestions based on observation
   e) Pupil transportation professional organization recommendations
   f) Traffic operations safety
10) Summary and Recommendations

Appendix B
Technical Appendix

Table B-1. Matrix to convert KABCO injuries to MAIS injuries

MAIS Injury score	MAIS Score meaning	KABCO Injuries				
		A	B	C	0	K
0	Minor Injury	0.01516	0.04938	0.19919	0.92423	0.07523
1	Moderate Injury	0.49183	0.79229	0.71729	0.07342	0.70581
2	Serious Injury	0.27920	0.12487	0.06761	0.00206	0.15708
3	Severe Injury	0.16713	0.03009	0.01509	0.00029	0.04343
4	Critical Injury	0.02907	0.00267	0.00064	0.00001	0.01712
5	Fatality	0.01762	0.00069	0.00018	0.00000	0.00134

Adapted from Willke, et al. (1999)

Table B-2. National MAIS injuries to pupils in school buses by point of impact

MAIS Injury Level	Total	Frontal	Side	Rollover	Rear and other
0	81389.88	23838.99	37003.10	24.03	20523.76
1	11296.34	2255.21	4572.56	114.00	4354.57
2	825.88	225.27	287.88	19.31	293.42
3	218.65	59.66	68.79	7.10	83.10
4	25.67	5.59	6.74	1.07	12.28
5	9.45	2.66	2.33	0.50	3.97
Total injuries	93765.87	26387.38	41941.39	166.00	25271.09
Fatal	5.1	1.3	1.2	1.8	0.8

Source: NHTSA (2008) Tables IV-5a, IV-5c, IV-6b, and IV-7b

Table B-3. NHTSA redistributed injuries and fatalities based on dummy type for large school buses

Dummy Type	No Injuries	MAIS 1	MAIS 2	MAIS 3	MAIS 4	MAIS 5	Fatal
6 year old	25,663.08	3,5054.6	242.59	64.23	6.02	2.87	0.41
5 % female	35,054.35	4,788.27	331.37	87.73	8.22	3.92.	0.56
50% male	20,895.58	28,54.24	197.53	52.30	4.90	2.34	0.33

Source: NHTSA (2008) Table 3a

Table B-4. Distribution of injuries and fatalities by dummy type, injured body region, and injury severity

Dummy Type	Injury Location	No Injuries	MAIS 1	MAIS 2	MAIS 3	MAIS 4	MAIS 5	Fatal
6 year old	Head Injuries	7,580.49	1,035.46	71.66	18.97	2.94	1.40	0.20
	Neck Injuries	3,646.35	498.08	34.47	9.13	1.85	0.88	0.13
	Thorax Injuries	4,303.30	587.81	40.68	10.77	1.89	0.90	0.13
5th percentile female	Head Injuries	10,354.54	1,414.38	97.88	25.92	4.01	1.91	0.27
	Neck Injuries	4,980.71	680.34	47.08	12.47	2.52	1.20	0.17
	Thorax Injuries	5,878.07	802.92	55.57	14.71	2.58	1.23	0.18
50th percentile male	Head Injuries	6,172.24	843.10	58.35	15.45	2.39	1.14	0.16
	Neck Injuries	2,968.96	405.55	28.07	7.43	1.50	0.72	0.10
	Thorax Injuries	3,503.86	478.61	33.12	8.77	1.54	0.73	0.10

Source: NHTSA (2008) Table V-6e

Table B-5. NHTSA findings on the probability of injury and effectiveness rate based on a 5th percentile female dummy; compartmentalization with standard seatbacks versus compartmentalization with tall seatbacks and lap/shoulder belts

Dummy Behind	Prob. of No Injuries	Prob. of MAIS I	Prob. Of MAIS 2	Prob. Of MAIS 3	Prob. of MAIS 4	Prob. of MAIS 5	Prob. of Fatal
H1C15 - Probability of Injury							
Compartmentalization, standard seatback height, lap belts	15.13%	38.81%	30.32%	12.20%	3.23%	0.30%	0.01%
Compartmentalization, + high back seatback, + lap/shoulder belts	85.96%	9.40%	3.01%	3.01%	0.33%	0.02%	0.00%
Effectiveness Rate (Percent Change)	-467.98%	75.78%	90.09%	90.09%	89.71%,	92.82%	95.90%
Nij - Probability of Injury							
Compartmentalization, standard seatback height, lap belts	65.74%	4.11%.	4.11%.	2.75%	10.77%	6.26%	6.26%
Compartmentalization, + high back seatback, + lap/shoulder belts	74.65%	4.68%	4.68%	0.00%	7.64%	4.17%	4.17%
Effectiveness Rate (Percent Change)	-13.55%	-13.88%	-13.88%	100.00%	20.08%	33.27%	33.27%
Chest g's - Probability of Injury							
Compartmentalization, standard seatback height, lap belts	42.92%	19.32%	19.32%	11.96%	6.29%	0.09%	0.09%
Compartmentalization, + high back seatback, + lap/shoulder belts	49.88%	17.93%	17.93%	9.42%	4.71%	0.06%	0.06%
Effectiveness Rate (Percent Change)	-16.21%	7.23%	7.23%	21.26%	25.02%	27.32%	27.32%

Source: NHTSA (2008) Table IX-1a

Appendix C
Acknowledgments

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Appendix D
Publications Produced during the
Alabama School Bus Seat Belt Pilot Project

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