Investigation of the Effects of Seat Belts on School Bus Capacity

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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**Abstract**

This study was one component of a comprehensive Alabama School Bus Seat Belt Project. It was conducted to determine the seating pattern of Alabama school buses after installation of lap/shoulder seat belts and the potential of various seat/row configurations to reduce capacity.

Two changes to school bus seatbacks reduce capacity. First, the belt buckle latches are installed 15 inches apart, which makes it impossible to seat three elementary-school pupils on one bench seat. Manufacturers are producing configurations with three seats on one side of the bus and two on the other (loss of one seat per row), or with slightly wider benches with three seats on both sides, but at a loss of aisle space. Second, seatbacks are thicker to accommodate the structural needs of seat belts. The extra thickness results in the loss of one or more rows of seats.

Five prior studies were found on this topic, conducted between 2002 and 2009 by NHTSA, Indiana, North Carolina, Texas, and the Congressional Reference Service. These studies identified the important issues and provided general (but not exact) estimates of capacity reduction and costs. Four of the studies identified capacity reductions of 17%, 0-17%, 8-17%, and 16-33% from installing seat belts. Four studies estimated costs for installation; the estimates ranged from $2,440-$3,550 in 2002 to $9,300-$14,000 in 2007.

**Analysis of Alabama School Buses**

The analysis was based on detailed data for 2,222 buses (30% of the state fleet), provided by transportation supervisors. Four seat configurations were analyzed. They represent the current seat and row arrangement (3/3-12: 12 rows of three seats on the left and three seats on the right), loss of a row of seats (3/3-11: 11 rows of three seats on the left and three seats on the right), loss of one seat per rows (3/2-12: 12 rows of three seats on the driver’s side of the aisle and two seats on the other side), and loss of both a row of seats and a seat per row (3/2-11: 11 rows of three seats on the driver’s side of the aisle and two seats on the other side). University Transportation Center for Alabama (UTCA) researchers created an equation to determine capacity for each bus in the data sample based on the current pupil loads. The equation determined the number of additional buses needed to carry existing pupil loads for all four configurations under consideration, as follows:

- 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
Through a careful assessment of the data, researchers concluded that the error in estimating the number of needed buses was less than 2%.

The study anticipated that two older pupils (high school or middle school) could sit on the 30-inch-wide bench in 3-2 seating. While it is doubtful that two large high-school pupils could sit on this seat, a driver can usually assign these seats to two not-so-large pupils.

**Flex Seats and Longer Buses**

Flex seats might help offset loss of capacity due to seat belts. Flex seats use adjustable lap/shoulder belts to provide lap/shoulder belts for two average-size high-school students or lap/shoulder belts for three elementary-school students. UTCA video observations, phone interviews with school systems in other states, and a field observation suggested flex seats work, especially for smaller pupils. However, flex seats squeeze aisle space. Row spacing appears to be a crucial issue to accommodate middle- and high-school pupils, and three to nine seats are lost depending on the length of bus purchased and the row spacing specified. Manufacturers can offset the loss of capacity by lengthening school bus seating compartments so no rows of seats are lost. However, doing so lengthens the wheel base, making the bus more difficult to control and requiring a larger turning radius. This is a detriment to bus control in small school parking lots and narrow, crooked rural roads.

**Unique Contribution of this Study**

This study makes two contributions to the knowledge of school bus capacity loss due to the installation of seat belts. First, a comprehensive literature review determines the state of knowledge and identifies major issues affecting capacity. Second, this is the first time that current pupil loads are tested on individual school buses for four seat/row configurations to determine the loss of capacity. In addition to these contributions, the study enhances understanding of the effectiveness of flex seats through video, in-bus observation of pupil use, and a telephone survey of school systems with experience using the seats.

**Recommendations**

This study recommends transportation supervisors analyze their fleets to identify the type of seat configuration that best fits their pupil base. Then they can select bus models that minimize loss of seating capacity while satisfying their pupil transportation needs. Many of the buses that are overloaded due to seat belts will carry only a few excess pupils. Transportation supervisors may be able to handle such overloads by transferring these pupils to other buses or by adjusting their bus routes to minimize the need for new buses.

**Summary**

This study provides information about the extent to which the installation of seat belts will affect the capacity of school buses. Quantitative estimates of capacity loss were calculated for various configurations of Alabama school buses. This information will assist the Alabama State Department of Education (ALSDE) and transportation supervisors in selecting the most safety-efficient and cost-efficient configuration of seats and seat belts to transport pupils in Alabama.

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Executive Summary

This study was one component of a comprehensive Alabama School Bus Seat Belt Project. It was conducted to determine the seating pattern of Alabama school buses after installation of lap/shoulder seat belts and the potential of various seat/row configurations to reduce capacity.

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Section 1
Introduction

1.1 Lack of a Consensus on School Bus Seat Belts

Despite their strong safety record, public sentiment is clearly shifting toward requiring seat belts on school buses. Seat belt advocates believe that seat belts will save lives and prevent injuries, but opponents do not see a scientifically justifiable reason for going beyond the current safety requirements, which make school buses the safest mode of roadway transportation.

Several advocacy groups promote the use of restraints on school buses. Among the most prominent is the National Coalition for School Bus Safety (NCSBS), which prepares fact sheets and brochures such as “Studies: Seat Belts in School Buses” (NCSBS 2005). The NCSBS refers to current school bus design as “compromised compartmentalization” and argues that the design works fairly well for front-end crashes but provides no passenger protection for side impacts and bus rollovers (NCSBS 2002). Strong support also comes from the medical community, which believes that seat belts will reduce the probability of serious injury and death and will improve the behavior of child passengers. The American Academy of Pediatrics and the American Medical Association are among the supportive groups (Reilly 1995).

In general, the education and transportation-safety community has been less enthusiastic toward school bus seat belts. This includes the National Highway Traffic Safety Administration (NHTSA), the US Department of Education (USDOE), the US Department of Transportation (USDOT), the National Safety Council (NSC), and the National School Transportation Association (NSTA) (Reilly 1995). These groups contend that there is little scientific research demonstrating that seat belts will significantly reduce severe injuries and deaths among bus passengers. NHTSA also argues out that the additional space requirements needed to add lap/shoulder belts can reduce the capacity of large school buses. This could mean that school buses might not accommodate some pupils or that more buses must be purchased. “If either of these caused a reduction in the number of riders in school buses, benefits gained by installing improved occupant protection devices could be offset as school children find alternative (and less safe) transportation to schools” (NHTSA 2002).

1.2 Alabama Pilot Study on School Bus Seat Belts

Few studies have been conducted to determine the impact of lap/shoulder seat belts on school bus capacity. The Alabama State Department of Education (ALSDE) instituted a novel project to determine the impact of such seat belts. ALSDE engaged the University Transportation Center for Alabama (UTCA) for a pilot study on a limited number of Alabama school buses (UTCA Project # 07407, “Pilot Study: School Bus Seat Belts”). Twelve school buses were equipped with various types of three-point or four-point seat belts and with four ceiling-mounted fish-eye digital cameras. The cameras produced data on restraint-use rate, pupil behavior, time
devoted to buckling at each stop, and other activities that affect safety, time in transit, and cost effectiveness.

The overall project is being conducted through several parallel initiatives that jointly provide the maximum amount of information about the adoption of school bus seat belts in Alabama. The research initiatives include the following:

1. Analysis of national practice – what other organizations and states have found, including analysis of prior safety studies;
2. Analysis of Alabama school bus crash data;
3. Alterations needed in the Alabama school bus fleet to accommodate seat belts;
4. Estimation of seat belt use rates;
5. Estimation of the effectiveness of seat belts in reducing fatalities and injuries; and
6. A cost-benefit analysis.

1.3 Objective of this Portion of the Pilot Project

This report addresses the third initiative of the project: potential fleet alterations to accommodate seat belts. The goals of this report include the following:

- Determine seating patterns for Alabama school buses after installation of lap/shoulder seat belts,
- Estimate the number and percentage of buses having insufficient capacity to carry the current number of pupils after the installation of seat belts, and
- Recommend ways to optimize the use of school buses with seat belts.

1.4 Review of School Bus Configurations

There are four types of school buses: A, B, C, and D. Types C and D are the largest, and they account for over 90% of all school buses (Nordberg 1998).

- “Type A: Suburban-Type Vehicle. This type has a weight rating of less than 10,000 pounds. It resembles a conventional Suburban-type vehicle and has a common capacity of eight pupils and a driver” (Nordberg 1998).
- “Type B: Standard Van or Chop-Van Chassis. With a weight rating of more than 10,000 pounds, this vehicle is constructed on a standard van or chop chassis, with a body added by the school bus manufacturer. It has a 16 to 24 passenger capacity” (Nordberg 1998).
- “Type C: Conventional. This type can be identified by the engine that protrudes at the front of the vehicle, ahead of the front windshield. It typically weighs 12 to 15 tons. The driver’s seat and main pupil entrance door are located behind the front axle” (Nordberg 1998). Type C buses can carry 48 to 71 pupils (ITRE 2007).
- “Type D: Flat-Nose. This type can be identified by a body that extends the full length of the chassis, giving it a characteristic "flat-nose" design. The driver's seat and primary entrance door are forward of the front wheels, with the engine located at either the front or rear of the vehicle” (Nordberg 1998). Type D buses can carry 48 to 71 pupils (ITRE 2007).
Today’s buses are configured with rows of seats flanking a central aisle. Typically, each seat is 39 inches wide, has a seatback 20 inches high, and holds three elementary-age children. Rows are 24 inches apart, and the aisle is 12 to 14 inches wide. Since three small pupils can sit on each side of the aisle, this is called a 3/3 configuration. An example is shown in Figure 1-1a (ITRE 2007). It is important to note that new buses must have seatbacks at least 24 inches high to meet recent NHTSA regulations (NHTSA 2008).

Type C and type D school buses equipped with lap/shoulder belts are configured differently than the same buses without the belts. First, the seatbacks are usually at least 28 inches high to accommodate the belt system, rather than the typical 20 to 24 inches. Second, the belt system will not accommodate three elementary-age children on a 39-inch bench, so fewer children can be accommodated in each row. One configuration allows five pupils per row, with three on one side of the aisle on a wider seat and two on the other side of the aisle on a narrower seat. This is called a 3/2 configuration and is shown in Figure 1-1b. When a school bus is anticipated to carry only larger pupils, a 2/2 configuration may be used with equal-width seats flanking a central aisle.

It appears flex seating can overcome the loss of capacity due to seat belts. Flex seats use adjustable lap/shoulder belts to provide lap/shoulder belts for two average-size high-school students or lap/shoulder belts for three elementary-school students. According to NHTSA (2007):

> Two manufacturers have introduced school bus seats with lap/shoulder belts on the common 39-inch-width bench seats, which allow the configuration of the belts to be flexible. Takata and their partner M2K (Takata/M2K) and IMMI both produce these types of flex-seat designs.... In their minimum-capacity configurations the seats will accommodate two 50th-percentile males per bench. In their maximum-capacity configuration they will accommodate three 10-year-old children on each bench.

NHTSA (2007) provided two other good pieces of information. First, they noted that integrating the seat belt anchors into the flex seat provides flexibility. Second, they reported a 2008 quote obtained by the Florida Department of Education that flex seats would add $10,336 to the cost of a bus with 12 rows.
1a: A typical 3/3 school bus seat without belts.  
1b: A typical 3/2 school bus with belts.  

Figure 1-1. Typical large school bus seating configurations (ITRE 2007)
Section 2
Previous Research

2.1 Indiana Study

A study of the possible loss of school bus capacity due to installation of seat belts was conducted by Dr. Thomas Steiger of Indiana State University. The objective was to analyze ridership data for Indiana school buses to estimate the impact of lap/shoulder restraints on the Indiana school-transportation system. The sample contained data from 6,200 bus routes, representing 127 Indiana school systems (about 40% of all school systems).

The Indiana study found that there are no explicit guidelines that control seating of pupils, but a common rule of thumb is that a 39-inch seat can hold either three elementary-school pupils or two middle/high-school pupils. Dr. Steiger called this seating arrangement “E/MH seating.” Using E/MH seating, the manufacturer’s estimated seat capacity is reduced more for 6th graders and above than for fifth graders and below. Hence, if a bus were designed to carry 66 passengers (the capacity of school buses if only K-5 pupils ride) and its bus route contained only riders in grades 6 through 12, E/MH seating would reduce capacity to 44, a one-third reduction.

This study estimated the impact of the installation of lap/shoulder belts on the ability to transport Indiana school children to and from school using three approaches. The first was to subtract observed riders from the manufacturer’s design capacity rating. Nearly half – 49.1% – of buses were running at greater than 75% capacity. The study suggested that the buses running close to capacity would expect the greatest effect of the installation of lap/shoulder belts. As a result, about half the bus routes would require larger buses, smaller routes, or additional buses to transport these pupils.

The second analysis modeled the seating of pupils on Indiana school buses by assigning each pupil on the bus a weight such that

1. K-5 pupil = 1/(manufacturer’s capacity) and
2. 6-12 pupil = 1.5 x (K-5 pupil).

This formula suggests just over 40% of bus routes would have insufficient capacity if E/MH seating were used.

In the third analysis, the seating guidelines modeled a one-third reduction of “in-use capacity” after installation of lap/shoulder belts. Steiger found just over 60% of bus routes would require additional seating. However, each school system will see different effects from the installation of lap/shoulder belts.
These three analyses suggest that lap/shoulder belts could significantly reduce capacity. Only three systems would go unaffected by the installation of lap/shoulder belts, while 45 of 127 school systems would have 75% or more of their routes affected.

2.2 North Carolina Study

The Institute for Transportation Research and Education (ITRE) conducted a study in North Carolina where 11 school agencies tested 13 buses equipped with lap/shoulder belts. The buses had 32-inch-high seatbacks, and the width of the seats was 45 inches on one side of the aisle and 30 inches on the other (a 3/2 configuration). This arrangement was chosen to preserve as much capacity as possible. However, experience showed that “because of the tight seating space, high-school pupils choose to sit two (rather than three) on a 45-inch seat and only one (instead of two) in the 30-inch-long seat as long as the bus is under-loaded to allow this flexibility” (ITRE 2007).

ITRE’s final report included an estimate of the reduction in seating capacity with various configurations (see Table 2-1). The table contrasts the numbers of elementary-, middle-, and high-school pupils that can be accommodated in 2/2 and 3/2 configurations with the number of pupils that can be accommodated in the conventional 3/3 configuration. In addition to the nominal number of pupils that can be accommodated by various lap/shoulder-belt configurations, the table also shows a “real world” estimate of the number of pupils that could be accommodated. In general, both the 2/2 and 3/2 configurations accommodate the same or fewer pupils than the 3/3 configuration. When the riders are smaller children, the 3/2 configuration may seat more pupils than the 2/2 configuration. When larger pupils are expected as riders, the 2/2 configuration may seat more pupils than the 3/2 configuration.

Table 2-1 indicates that the addition of lap/shoulder belts may significantly increase the size of the bus fleet required to transport pupils, depending on the numbers and ages of pupils expected on individual school bus routes.

<table>
<thead>
<tr>
<th>Type of School</th>
<th>Conventional Bus without 3-pt. Belts</th>
<th>Equivalent Bus with 3/2 Seats</th>
<th>“Real World” Operating Seating Capacity (3/2)</th>
<th>Equivalent Bus with 2/2 seats</th>
<th>“Real World” Operating Seating Capacity (2/2)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Elementary</td>
<td>71</td>
<td>59</td>
<td>59 or 35</td>
<td>48</td>
<td>48</td>
</tr>
<tr>
<td>Middle</td>
<td>59</td>
<td>59</td>
<td>59</td>
<td>48</td>
<td>48</td>
</tr>
<tr>
<td>High</td>
<td>48</td>
<td>59</td>
<td>35</td>
<td>48</td>
<td>48</td>
</tr>
</tbody>
</table>

Source: ITRE (2007).

The ITRE report further indicates that in addition to the potential cost of purchasing a larger fleet, the cost of the lap/shoulder belts themselves must be considered. A seat manufacturer estimated the cost of installation of a lap/shoulder belts at about $7,700 per bus (ITRE 2007). In addition to installation cost, School Transportation News estimated that “maintaining, repairing, and replacing damaged belts can add $100 to $500 per bus to annual maintenance costs” (STN Media Group 2007). More information about the costs of seat belts is provided later in this report.
The seat belts require seats that have increased strength (3,000 pounds on each belt anchor [NHTSA 2008]) to handle the shock loads placed on the belts at impact. Such strong seats need a stronger frame with a thicker seatback; various seat manufacturers report that seatbacks will become five to seven inches thick. Since current seats are three inches thick, each row of new seats requires two to four more inches of space. A normal bus would need an additional 24 to 48 inches to accommodate all 12 of its rows. In other words, current buses do not have enough space to hold 12 rows of new seats, so at least one row of seats would be lost, and possibly two. This would be a loss of 8% to 17% of current seat capacity.

The ITRE report indicates bus manufacturers are aware of this issue and are considering producing longer seat compartments to accommodate the new seats. But this change brings its own challenges. For one, the bus wheel base must be extended. This means the bus will require a bigger turning radius, which will make handling and turning more difficult in crowded school drop-off/pick-up areas and on many old, narrow roads. For purposes of the ITRE study, all buses were assumed to lose one row of seats due to increased seat thickness. However, it might be possible that 12 rows are available at some point in the future if bus manufacturers extend passenger compartments.

2.3 Congressional Research Service Study

Congress has periodically shown strong interest in the topic of seat belts on school buses. Congress requested studies about seat belts on school buses through the Motor Vehicle and School Bus Safety Amendments of 1974 (P.L. 93-492) and the 1998 Transportation Equity Act for the 21st Century (P.L. 105-134). The most recent was published in a Congressional Research Service (CRS) report titled “Seat Belts on School Buses: Overview of the Issue” (CRS 2007).

The CRS report indicated that the cost of equipping a large school bus with three-point lap/shoulder seat belts could range from $8,000 to $15,000. Based on estimated annual sales of roughly 31,000 new large school buses, the annual additional capital cost of equipping the nation’s fleet of large school buses with lap/shoulder belts could be in the range of $250 million to $465 million. This represents an increase of roughly 10% to 20% in annual spending on large school buses. The report also addressed the impact on seating capacity when lap/shoulder belts are added to large school buses. The report stated that buses with lap/shoulder belt systems would have either 2-2 seating or 3-2 seating instead of 3-3 seating. The report is directed at type C and type D buses with seating capacities between 60 and 84 elementary-age pupils, based on 10 or more rows of two seats, each 39 inches across, with three pupils to a seat and six to a row (3-3 seating). Hence, the addition of lap/shoulder belts to these buses will typically reduce the elementary-school pupil-seating capacity between 16% and 33%.

Finally, the CRS report proposed several options for Congressional action: (1) maintain the status quo, (2) require lap/shoulder belts on large school buses, (3) encourage the purchase of large school buses with lap/shoulder belts, or (4) pursue alternative safety initiatives. Alternative safety initiatives include shifting pupils from more dangerous modes of transportation to school (such as bicycling, walking, and passenger vehicles driven by teens) to safer modes (such as school buses). Other options include making school bus and passenger-vehicle pick-up and
drop-off locations safer, implementing and enforcing graduated licensing programs for teen drivers, and equipping school buses with onboard data recorders.

2.4 Texas Study

The Legislative Budget Board Staff of the Texas State Government prepared a report titled “Texas State Government Effectiveness and Efficiency: Selected Issues and Recommendations” (LBBS 2009). Implementing the school bus lap/shoulder seat belt requirement is among the many issues addressed in this report.

The Texas report included survey responses from approved school bus vendors about cost estimates for the addition of lap/shoulder seat belt restraints on a 72-passenger type C school bus. The cost estimates for lap/shoulder seat belt restraints ranged from $9,300 to $14,000, with an average of $12,433. Equipping all 2,500 72-passenger buses purchases annually with lap/shoulder seat belts at $12,433 each would result in an additional statewide cost of approximately $31.1 million annually. Assuming that school districts continue to purchase buses at the same rate and that the type C model bus continues to be the most common bus used to transport Texas pupils, it could take approximately 15 years to replace the 37,599 current buses in Texas with buses with lap/shoulder seat belts.

The report noted that many leaders in the Texas school-transportation industry are concerned that districts will incur the costs of installing, maintaining, and operating the seat belts. It further states that the loss of seating capacity could reduce the number of riders per route, which could decrease a district’s reimbursable mileage rate and require additional buses and drivers to operate additional bus routes, leading to increased maintenance and operation costs.

The report proposes two options to consider with regard to the implementation of lap/shoulder seat belts on Texas school buses: (1) provide a monetary incentive for districts and (2) coordinate the purchase of buses. Under the monetary-incentive policy, if districts purchase large school buses with lap/shoulder seat belts, then they could be offered a monetary incentive for doing so, even if not a full reimbursement. To receive this incentive, districts would be required to submit a comprehensive seat belt policy and a bus-replacement plan and schedule to the state. The second option, a state-coordinated bus-purchasing policy, would create opportunities for the state to help districts reduce the cost of bus purchases by absorbing some of the additional cost associated with the lap/shoulder seat belts.
2.5 Estimates of Cost Increases and Capacity Reductions

For comparative purposes, the costs and potential reductions in capacity discussed in this section of the report are summarized in Table 2-2. This table includes comparative data from NHTSA; the Governments of North Carolina, Indiana, and Texas; and the CRS.

<table>
<thead>
<tr>
<th>Study</th>
<th>Date</th>
<th>Cost per Bus</th>
<th>Possible Capacity Reduction</th>
</tr>
</thead>
<tbody>
<tr>
<td>NHTSA Report to Congress (2002)</td>
<td>2002</td>
<td>$2440 to 3550*</td>
<td>17%</td>
</tr>
<tr>
<td>Indiana School Bus Study (Steiger 2005)</td>
<td>2005</td>
<td>-</td>
<td>0 to 33%</td>
</tr>
<tr>
<td>NC State School Bus Study (ITRE 2007)</td>
<td>2007</td>
<td>$7,700</td>
<td>8 to 17%</td>
</tr>
<tr>
<td>CRS Report for Congress (2007)</td>
<td>2007</td>
<td>$8,000 to 15,000</td>
<td>16 to 33%</td>
</tr>
<tr>
<td>Texas State Government (LBBS 2009)</td>
<td>2009</td>
<td>$9,300 to $14,000</td>
<td>-</td>
</tr>
</tbody>
</table>

* The cost of a lap/shoulder seat belt, $40 to $50, is multiplied by 60 to 71 seats to get the total cost for a bus.
Section 3
Alabama Analysis Procedure

The Alabama pilot study analyzed the capacity of various seat configurations based on (1) the number of rows and seats per row; (2) the number of pupils per seat based on elementary-, middle-, or high-school pupil size; and (3) the number of pupils currently assigned to each route. For each bus, the analysis compared the current configuration with the potential configurations after seat belt installation. Since 12 is the most common number of rows on Alabama school buses, a simple way to say this is that the current configuration of 3/3-12 was compared to proposed arrangements such as 3/2-11 (that is, seat belt installation removes one seat per row and one row).

The actual comparison is slightly more complex than this for at least three reasons:

- Not all buses lose one row of seats when seat belts are installed. The number of rows lost differs.
- Although the dominant number of rows for large buses is 12, the Alabama fleet has about 50 buses with 13 or 14 rows of seats. So the analysis actually compared (3/3 seating and $R$ rows of seats) to (3/2 seating and $R-1$ rows of seats), where $R$ is the actual number of rows of seats on a given bus. Since it is awkward to state the exact number of rows for each bus for each analysis, for the remainder of this report “12 rows” represents the current number of rows on a bus and “11 rows” represents the number of rows after installation of seat belts.
- If bus manufacturers expand bus compartments to compensate for the loss of a row due to thicker seatbacks, 12 rows is still possible.
- If experience shows flex seat performs well, it might be possible to retain part or all of the seats lost from installing lap/shoulder seat belts.

The analysis specifically addressed four seat arrangements: 3/3-12, 3/3-11, 3/2-12, and 3/2-11. Flex seating was not specifically analyzed because it approximates the 3/3-11 and 3/3-12 configurations. Two datasets were used in the study. The initial analysis used the standard Route Report produced by local school systems each fall. The quality and completeness of these data were unknown, and some desired data were unavailable. To overcome these data limits, school-system transportation supervisors provided another dataset containing pupil ages and more details about routes and pupil pick-up/drop-off locations.

3.1 First Analysis – Route Report Data

The initial analysis used the Route Report, which contains data collected and submitted annually by all public school systems to the Pupil Transportation Section of ALSDE using a web-based system. It contains details of school buses and routes for 67 counties and 66 cities. The data tables are related and linked to one another. One table was particularly useful for this study: the “Route Detail” table. For each bus, it contained the route identification, bus number, route type,
system code, route number, route duration, distances traveled while occupied and unoccupied, number of pupils, and types and numbers of schools served. Table 3-1 shows sample records contained in the Route Detail table.

A close examination of the data identified several errors and outliers. For example, different school systems were found to have identical bus numbers. Most of these errors were overcome, but if they could not be resolved the affected records were removed from the dataset. The resulting dataset included useful information for 7,547 school buses.

### Table 3-1. Sample records in the route detail table

<table>
<thead>
<tr>
<th>RouteID</th>
<th>Bus Number</th>
<th>System Code</th>
<th>Bus Number and System</th>
<th>RouteType Desc</th>
<th>Route Number</th>
<th>Route Duration</th>
<th>Occupied Distance</th>
<th>Unoccupied Distance</th>
<th>Number Transported</th>
<th>ELEM</th>
<th>MSJH</th>
<th>HIGH</th>
<th>UNIT</th>
</tr>
</thead>
<tbody>
<tr>
<td>3376</td>
<td>00-00001</td>
<td>055</td>
<td>00-00001055</td>
<td>Regular Route</td>
<td>0001</td>
<td>80</td>
<td>27</td>
<td>2</td>
<td>33</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>6971</td>
<td>00-00001</td>
<td>056</td>
<td>00-00001056</td>
<td>Special Needs</td>
<td>0027</td>
<td>165</td>
<td>44</td>
<td>17</td>
<td>2</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>1453</td>
<td>00-00001</td>
<td>057</td>
<td>00-00001057</td>
<td>Regular Route</td>
<td>0026</td>
<td>50</td>
<td>22</td>
<td>2</td>
<td>44</td>
<td>0</td>
<td>1</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>1019</td>
<td>00-00001</td>
<td>058</td>
<td>00-00001058</td>
<td>Regular Route</td>
<td>0089</td>
<td>60</td>
<td>12</td>
<td>4</td>
<td>60</td>
<td>1</td>
<td>2</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>5120</td>
<td>00-00001</td>
<td>059</td>
<td>00-00010059</td>
<td>Regular Route</td>
<td>0601</td>
<td>49</td>
<td>13</td>
<td>5</td>
<td>50</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>8720</td>
<td>00-00001</td>
<td>060</td>
<td>00-00010060</td>
<td>Regular Route</td>
<td>0041</td>
<td>45</td>
<td>11</td>
<td>0</td>
<td>54</td>
<td>0</td>
<td>1</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>9569</td>
<td>00-00001</td>
<td>061</td>
<td>00-00010061</td>
<td>Regular Route</td>
<td>0060</td>
<td>38</td>
<td>14</td>
<td>0</td>
<td>43</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>4654</td>
<td>00-00001</td>
<td>001</td>
<td>00-00010001</td>
<td>Special Needs</td>
<td>0119</td>
<td>90</td>
<td>24</td>
<td>2</td>
<td>5</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>1637</td>
<td>00-00001</td>
<td>102</td>
<td>00-00001102</td>
<td>Regular Route</td>
<td>0002</td>
<td>35</td>
<td>10</td>
<td>4</td>
<td>45</td>
<td>3</td>
<td>1</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>11102</td>
<td>00-000001</td>
<td>014</td>
<td>00-00001104</td>
<td>Regular Route</td>
<td>0009</td>
<td>75</td>
<td>13</td>
<td>3</td>
<td>61</td>
<td>1</td>
<td>1</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>11851</td>
<td>00-00001</td>
<td>110</td>
<td>00-00001110</td>
<td>Regular Route</td>
<td>0089</td>
<td>35</td>
<td>13</td>
<td>5</td>
<td>36</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>13074</td>
<td>00-00001</td>
<td>110</td>
<td>00-00001110</td>
<td>Regular Route</td>
<td>0035</td>
<td>15</td>
<td>5</td>
<td>2</td>
<td>10</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

### 3.1.1 Capacity Analysis for Route Report Data

The researchers developed a series of tests to help determine whether an existing bus had enough extra capacity to carry its current load of pupils after the installation of seat belts. For example, if a bus delivered pupils to only one elementary school, then all the pupils were elementary age and the bus could be examined for changes in capacity for different seat and row configurations. However, not enough data were available for all buses, so not all of them could be analyzed in this manner. The analysis also made assumptions about the number of pupils that could sit in various seats configurations:

- For a 3/3 configuration, the seats on both sides of the bus can hold either three elementary-school pupils or two middle/high-school pupils.
- For a 3/2 configuration, the wider seat can hold three elementary- or two middle/high-school pupils. The narrower seat can hold two pupils of any size.

The Route Detail table contained the number of pupils transported by each school bus on its assigned routes, but it did not specify the number of elementary-, middle-, and high-school pupils transported. The split could often be deduced, but when it could not, additional reasonable assumptions helped provide a range of estimates:

1. If a bus transported pupils exclusively to one type of school (elementary, middle, or high school), the researchers assumed the pupils on the bus were in the same age group and the new capacity was estimated using the assumptions in the previous paragraph.
2. For a bus transporting pupils to more than one type of school, the new capacity could not be determined with certainty because the passenger ages were unknown. The researchers produced multiple estimates for these buses:
   a. One estimate was prepared assuming all pupils of unknown age were from middle/senior-high schools. These groups occupy more seat space than elementary-school pupils, so this assumption leads to the maximum number of new buses needed after installation of seat belts.
   b. A second estimate was made assuming all pupils of unknown age were from elementary schools. Pupils in this group occupy less seat space than middle/senior-high pupils, so this assumption gives the minimum number of new buses needed after installation of seat belts.

The new capacity for each bus was compared to the number of pupils transported. This identified whether buses with seat belts meet existing demand.

3.1.2 Findings from Route Report Data

Figure 3-1 displays the results for buses with a 3/2-11 configuration assuming the pupils, whose sizes are unknown, are elementary-school age. Totaling the boxes in the Figure gives an estimate of the maximum number of buses that might have sufficient capacity for their current pupils after installation of seat belts in a 3/2-11 configuration.

A closer examination of Figure 3-2 shows the logic. At each branch of the Figure, the logic decision is displayed along with the number of buses assigned to each logic branch. For example, at the top of the Figure “total buses” is displayed along with the number of buses in that category (7547). Moving down a level, the key issue (decision) is how many routes does this bus run? for which there are three possible answers: one, two, or more than two. There were 6162, 1165, and 220 buses in these respective categories. It is possible to follow the entire logic tree to determine that 4838 buses (64%) would meet the new capacity requirements while 2709 (36%) would not (using an assumption about pupil size that gives the maximum estimate of new buses needed after installation of seat belts).
Analysis of Route Detail data provided a good introduction to pupil loadings and routes, but there were two limitations to the data that prohibited a precise analysis: (1) it did not contain the number of seats on individual buses (the manufacturer’s [OEM] certification of the number of seats) and (2) it did not distinguish age differences (the split between elementary- and middle/high-school pupils was not available). Where logic could not deduce this split for a specific bus, the researchers used assumptions about age to estimate the minimum and maximum numbers of students on a specific bus. Although uncertainty remained, the assumptions allowed a reasonable estimate range of additional buses needed after installation of seat belts. The range is illustrated in Table 3-2.
Table 3-2. Estimated minimum and maximum number of school buses with insufficient capacity to install seat belts (Route Report data)

<table>
<thead>
<tr>
<th>Buses Analyzed</th>
<th>Seat/Row Assumption</th>
<th>Min Buses with Insufficient Capacity</th>
<th>Max Buses with Insufficient Capacity</th>
</tr>
</thead>
<tbody>
<tr>
<td>7327</td>
<td>3/3-12 rows (max load)</td>
<td>255 (4%)</td>
<td>2395 (33%)</td>
</tr>
<tr>
<td>7327</td>
<td>3/3-11 rows</td>
<td>557 (8%)</td>
<td>3037 (41%)</td>
</tr>
<tr>
<td>7327</td>
<td>3/2-12 rows</td>
<td>1033 (14%)</td>
<td>2500 (34%)</td>
</tr>
<tr>
<td>7327</td>
<td>3/2-11 rows (min load)</td>
<td>1651 (23%)</td>
<td>3182 (43%)</td>
</tr>
</tbody>
</table>

Table 3-2 indicates that if a 3/3-11 configuration is installed, 8% to 41% of existing buses lack the capacity to carry their existing pupil loads. Similar estimates are provided for the other three configurations.

3.2 Second Analysis – Transportation-Supervisor Data

To overcome the limitations of the Route Report data, UTCA researchers requested ALSDE to collect data on the number of elementary-, middle-, and high-school pupils transported in each school bus. UTCA researchers also requested data to clarify two special situations: some buses appeared to pick up passengers between school drop-offs on a given route and other buses appeared to combine pupil age groups across all routes, rather than identifying the age distributions for the legs of each route for given bus. To assist in collecting these data, UTCA researchers created a data form (see Figure 3-3) and developed data definitions.

On the form, *Other Riders* indicates pupils who are loaded after the bus makes its stop at the first school on the route. An example is a bus carrying 56 pupils of which 32 are in elementary school. It drops the elementary-school pupils at their school then picks up 14 middle-school and 6 high-school pupils – the “other riders.” The field *Order of Schools* refers to the order of school destinations. It is used to determine the age group(s) that leave the bus at any school destination (in this above example, 32 pupils were dropped off at the first destination, an elementary school).

ALSDE requested the desired data from transportation supervisors. There was a good response: data were collected for 2780 school buses and 3236 unique routes. This allowed analysis of both buses and routes, if needed. A sample of the data collected from the Barbour County school system is shown in Table 3-3.

3.2.1 Assessment of the Data

The UTCA researchers spent time exploring the data. The purpose was to develop an initial understanding of the data and the relationships between variables and to identify erroneous data entries and outlier data points. This involved manual scans, plotting and tabulating data, and conducting simple analyses.
The first finding was that some buses were transporting more pupils than their age-specific capacities would seem to allow. ALSDE called a sample of local school systems to investigate. Many buses were indeed carrying one or more pupils beyond bus capacity for the involved age groups. The reasons were not determined, but it could have been small middle-school pupils who sat three to a seat. This overloading added a degree of uncertainty to conclusions that could be drawn during the study.
Another finding involved the capacities of the buses in the dataset. Some type A and type B buses (small buses) and others had unusual capacities. After consultation with ALSDE, the data were restricted to buses with manufacturer-estimated capacities of 71-72 and 83-83 (typical types C and type D school buses). This removed 129 buses from the dataset.

A third finding was that some transportation supervisors misunderstood the meaning of Other Pupils when providing data. Some buses appeared to be substantially overloaded, but closer examination revealed that transportation supervisors had erroneously added all pupils riding the bus on a given route, including those picked up at school for transport to another school. Another 429 buses were removed for this reason, leaving 2,222 buses and 2,536 routes in the database. The sample included 30% of the ALSDE school bus fleet, a generous size for this study.

### 3.2.2 Methodology for Analysis for Transportation Supervisor Data

A new analytical method was created to utilize the additional data provided by the transportation supervisors. A formula was utilized to calculate the capacity of each bus after seat belts are installed. The formula was needed because capacity varied with the number of elementary-school pupils. The formula and variable definitions for a 3/3-11 configuration are shown:

\[
C_{\text{new}} = E + \left(22 - \frac{E}{3}\right) \times 2
\]

where

- \(C_{\text{new}}\) is the new capacity of a school bus after installation of seat and lap belts and
- \(E\) is the number of elementary-school pupils transported by the bus.

The equation produces different capacity values depending on the number of elementary-school pupils on a bus. For the 3/3-11 configuration, the maximum capacity of 66 can only be reached when the bus carries only elementary-school pupils. Likewise, the maximum capacity is 44 if the bus carries only middle/high-school pupils. For this configuration and a mix of elementary- and middle/high-school pupils, the new capacity falls between 44 and 66 pupils and can be calculated using Equation 1. When the equation produces an answer with a decimal value, it is rounded down to the nearest integer. For example, if the calculated capacity is 48.3 pupils it is rounded down to 48 because a pupil cannot sit on 0.3 of a seat.

Table 3-4 shows the new capacities for a sample of buses from the City of Bessemer. Bus 01-00002 is overloaded on one of its routes, and bus 01-00004 is overloaded on its only route.

### 3.2.3 Importance of Order in Which Age Groups Board

The number of elementary-school pupils on a bus is key to capacity loss, while the order in which the pupils board the bus and where they sit are secondary.

For example, if a 3/3-12 bus is fully loaded with 72 elementary-school pupils and that bus converts to a 3/2-11 configuration after seat belts are added, the new capacity is 55 elementary-
school pupils. When the same bus initially holds 48 high-school pupils and converts to 3/2-11, the new capacity is 44. This bus can be over capacity by 4 to 17 pupils, depending on the mix of age groups.

When there is a combination of age groups on a bus, the order in which they board and where they sit are important. Most school systems prepare seating charts and assign pupils to specific seats, so elementary-school pupils are assigned to the three-seat side of the bus to prevent two older students from occupying a three seat, thereby reducing capacity. When the three-seat side of the bus is full, elementary-school pupils may spill over to the two-seat side.

Consider again a bus with a maximum capacity of 66. The bus would be full carrying 54 elementary- and 12 high-school pupils. If it is converted to a 3/3-12 configuration and the 54 elementary-school pupils load first, they would occupy all of the three-seat rows (33 pupils) and seven two-seat rows. When the 12 senior-high pupils try to load only four rows are available, so 8 senior-high pupils can sit and the bus is 4 pupils over capacity. When the boarding order is reversed so that senior-high pupils load first, they occupy 6 of the two-seat rows. The elementary-school pupils can use the 5 remaining two-seat rows on the door side and all 11 three-seat rows. Then 48 pupils are seated, leaving 6 elementary-school pupils without seats. Given the best possible seating pattern, this bus’s current pupil load will be four to six pupils over capacity after seat belts are installed, depending on the order of loading.

In summary, if a full 3/3-12 bus converts to a 3/2-11 configuration, it can be 4 to 17 pupils over capacity, with the greatest capacity loss for a load of elementary-school pupils and the least capacity loss for a load of older pupils. The split in elementary- vs. middle/high-school pupils, where they sit, and the order in which they board also varies bus capacity.

There are differences between theoretical capacity and real pupils on real buses. On a typical route pupils do not board in age groups; they board from their homes and several age groups may board at a single stop. Transportation supervisors and drivers can achieve maximum capacity for a bus by assigning seats based upon pupil ages (that is, ensuring that elementary-school pupils sit three to a seat), regardless of where along the route individual pupils board the bus.
3.2.4 Verification of Methodology

Equation 1, used to analyze the transportation-supervisor data, was verified using a random sample of 135 buses (about 5%) from the data pool. The sample included a range of bus sizes, pupil ages, and pupil loads. This sample was analyzed with a spreadsheet and the results were checked by hand. The estimates were identical, which provided confidence in the software analysis.

3.2.5 Findings from Analysis of Transportation Supervisor data

The capacity of each bus after seat belt installation was established for the four configurations of seat belts and rows. If a bus ran more than one route and the required information was unavailable for one of these routes, then that particular bus could not be analyzed.

Table 3-5 provides answers to the pressing issue of capacity reduction when seat belts are installed (neglecting the possibility that the flex seat might offset capacity reduction). Pupil data from existing routes in Alabama were used to produce the estimate. The Table gives the estimated percentage of current buses with insufficient capacity to handle their current loads with seat belts for four row and seat configurations. The current 3/3-12 configuration is the most efficient. This is logical since it the other three represent a loss of rows, seats, or both.

<table>
<thead>
<tr>
<th>Source of Data</th>
<th>Buses/Routes</th>
<th>Seat/Row Configuration</th>
<th>Estimate of Buses Not Meeting Capacity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Transportation</td>
<td>2,222</td>
<td>3/3 - 12 rows</td>
<td>68 (3.1%)</td>
</tr>
<tr>
<td>Supervisors</td>
<td>Buses</td>
<td>3/3 - 11 rows</td>
<td>365 (16.4%)</td>
</tr>
<tr>
<td>Detailed Data</td>
<td></td>
<td>3/2 - 12 rows</td>
<td>145 (6.6%)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>3/2 - 11 rows</td>
<td>445 (20.0%)</td>
</tr>
</tbody>
</table>

The study assumed two older pupils (middle school or high school) could sit on the narrower 30-inch-wide bench in 3-2 seating. While it is doubtful that two large high-school pupils could sit on this seat, a driver can usually assign these seats to two smaller pupils.

Using the reported fall 2009 pupil loads applied to the current configuration (3/3-12), the analysis suggested the current, unmodified bus fleet needs to grow 3%. As indicated earlier, some buses in the data appeared to be carrying more than their theoretical capacities given their mix of pupils. That could explain why some of the buses – maybe 1% or more – were already over capacity, meaning the data-error rate is less than 2%. As a result, the calculated values in Table 3-5 contain a small data-error of unknown magnitude, but it is probably less than 2%. The most likely causes of the error are clerical mistakes and number padding by bus drivers or transportation supervisors.

3.2.6 Assessment of Accuracy

Two techniques were used to assess the accuracy of the calculations. The first method was to compare the results of the Route Report analysis to the results of the transportation-supervisor analysis. The results appear in Table 3-6 and Figure 3-3.
There are several things of note in Table 3-6 and Figure 3-3:

1) The Route Report analysis could not calculate specific capacities due to the lack of key data. Instead, a reasonable range was established. The range varied from 20 to 33 percentage points, depending on the configuration. The range is so wide that it can be used only for identifying general trends, not for specific answers.

2) The transportation-supervisor data allowed direct calculation of estimates for each configuration. The accuracy of these calculations was limited by the quality and accuracy of the data. The exact error is unknown, but extensive assessment of the data led the researchers to conclude that it was less than 2%.

3) The transportation-supervisor results are considerably lower than the average (midpoint) of Route Report results. Estimates for three of the four configurations were smaller than the minimum estimated value of the Route Report analysis. There is a higher degree of certainty for the transportation-supervisor analysis.

4) The transportation-supervisor analysis used the current load on each bus to test each configuration. The methodology loaded pupils by age group until the capacity of a bus was exausted or all pupils were seated. The transportation-supervisor analysis produced a superior estimate.
5) Conclusions 3 and 4 indicate that the transportation-supervisor analysis yielded better results than the Route Report analysis. Indeed, both ALSDE managers and a sample of transportation supervisors believe the Route Report data are less complete and less accurate than the transportation-supervisor data.

The second assessment of accuracy was a comparison of estimated capacity losses for individual buses against the maximum theoretical losses for various configurations. The current 3/3-12 configuration provided the basis for calculating theoretical losses and the other three configurations in Table 3-7. The table shows theoretical capacity losses of 9% to 31% for elementary-school pupils. The actual loss of capacity will not always match these values because some elementary-school pupils are large and cannot sit three to a seat. Likewise, some middle-school pupils are small and can sit three to a seat.

<table>
<thead>
<tr>
<th>Configuration</th>
<th>Why Seats are Lost</th>
<th>Total Seats</th>
<th>Seats Lost</th>
<th>Theoretical % seats lost</th>
</tr>
</thead>
<tbody>
<tr>
<td>3/3 – 12</td>
<td>Current loading</td>
<td>72</td>
<td>0</td>
<td>0%</td>
</tr>
<tr>
<td>3/3 – 11</td>
<td>Lose 1 row of seats</td>
<td>66</td>
<td>6</td>
<td>9%</td>
</tr>
<tr>
<td>3/2 – 12</td>
<td>Lose 1 seat per row</td>
<td>60</td>
<td>12</td>
<td>17%</td>
</tr>
<tr>
<td>3/2 - 11</td>
<td>Lose 1 row and 1 seat per row</td>
<td>55</td>
<td>17</td>
<td>31%</td>
</tr>
</tbody>
</table>

For analytical purposes, the buses were grouped in Table 3-7 by configuration and by number of pupils over capacity. It is revealing to compare the theoretical maximum loss of seats in Table 3-7 with the calculated values shown in Table 3-8. The only instance in the table where buses exceeded the maximum theoretical limit was the 3/3-12 configuration, where 68 buses had one pupil above capacity. This anomaly has been mentioned previously in this report; the data indicate about 3% of all school buses in the dataset are now operating beyond capacity. Table 3-8 provides additional information about bus overload.
The Table provides good news. For the three proposed seat belt configurations, the analysis of transportation-supervisor data appears to provide realistic results, within the limits of the theoretical losses. They also identify 68 buses with 3/3-12 configurations that are currently running overloaded by a single pupil.

Since the base condition (current 3/3-12 configuration) represents as much as 2% error, UA researchers concluded that it was reasonable to reduce the over load percentages in Table 3-5 to 1%, 14%, 5% and 18% for the 3/3-12, 3/3-11, 3/2-12 and 3/3-11 configurations respectively.

### 3.3 Reducing the Number of Additional Buses Needed

A large number of school buses will have insufficient capacity once seat belts are installed. Table 3-6 shows that 20% of the current fleet will have insufficient capacity for a 3/2-11 configuration and 16% of the fleet will have insufficient capacity for a 3/3-11 configuration. But in some buses the capacity is exceeded by only a few pupils, as shown in Table 3-8. For a 3/2-11 configuration, 95 buses (21% of the sample) were over capacity by only one pupil and 238 (53% of the sample) were overloaded by three or fewer pupils. 378 were overloaded by six pupils or fewer (85% of the sample). Removing a few pupils can drastically change the “over capacity” status of many buses.

Table 3-8 provides guidance for reducing the number of additional buses that must be purchased after the installation of seat belts. For a 3/3-11 configuration, about half the overloaded buses would no longer be overloaded if one seat could be moved to another bus or another seat configuration could be adopted. About 21% of these overloaded buses would be one pupil above capacity, so moving one pupil can bring the bus within capacity.

Given Table 3-8, it is possible that school systems could make adjustments to minimize the impact of capacity loss due to seat belts, especially when capacity is exceeded by only a few pupils. Other methods might reduce the number of additional buses needed:

1. If not already doing so, assign pupils to specific seats so that three young pupils sit on the three-seat side of the bus (rather than two older pupils) to preserve capacity.
(2) For buses carrying only middle-school and high-school pupils, capacity could be maximized using a 2/2 configuration. These buses would lose one row of seats due to thicker seatbacks (one row lost out of 12 = 8.5% capacity loss).

(3) State departments of education and school systems could encourage bus manufacturers to extend buses to make up for the row loss due to thicker seatbacks. It is prudent for these school systems to analyze their school drop off/pick up locations to determine if the longer wheelbase would prohibit sharp turns into bus loading areas or on older, narrower roads.

(4) School systems could purchase type D buses with expanded capacity – 14 rows compared to 12 rows for type C. These buses could provide 70 seats with a 3/2 configuration (assuming no loss of rows due to thicker backs). The school systems might analyze their school drop off/pick up areas and narrow roads to ensure that the longer buses can make the required turning movements.

(5) Transportation supervisors could adjust their bus routes. This would involve review of their fleets and study of routes with insufficient capacity after seat belt installation. This could produce more efficient route arrangements and minimize the number of new buses purchased. This might be as simple as shifting three to six pupils to an adjacent route that is under capacity. As shown in Table 3-8, as many as 50% of the overloaded buses could be unloaded to the point that they could continue to run their current routes.

(6) Some buses could run additional routes. Currently some school systems pay driver and aide salaries based on a fixed number of work hours each day. In some instances it is possible to run two short or medium length routes within the allotted work hours each day. This schedule could accommodate additional pupils without buying new buses or hiring additional staff members.

(7) The state requires a waiver for pupils who live within two miles of a school to use the school bus. Some capacity could be regained if the state rescinds the waiver.

3.4 Impact of Flex Seats and Longer Seating Compartments

3.4.1 Flex Seats

One of the goals of this project was to observe the operation of various types of seats and seat belts. Four of the twelve pilot-project school buses were outfitted with flex seats, which appear to offset the loss of seating capacity. Unfortunately, all four had small pupil loads, so pupils rarely filled the seats to capacity (that is, there were rarely three elementary-school pupils to a seat). This did not allow observation of the seats under varying pupil loads or whether the pupils used the seats appropriately.

During the last weeks of the 2010 school year, the pupils were arbitrarily assigned seat locations that forced them to fill some flex seats. UTCA student researchers observed them via video, and a manager from ALSDE rode one of the buses to observe use of the seats. The observer rode a bus that carried K-5 pupils. Seat belt use was high and pupils were well behaved throughout the route.

Of particular concern were the spacing of rows of flex seats and the width of the aisle. Flex seats measured 21.5 inches from the back of the seat to the front of the next seat for all but the first
two rows, which were 22.5 inches. The typical seat bottom was 15.5 inches wide and 6 inches behind the next seat. The ALSDE observer had to turn his legs sideways to sit in the seat. The aisle was 12.5 inches wide, which could prove difficult for large pupils. The aisle width effectively narrows when pupils sit on the bus because they extend into the aisle.

The observer’s main take was that the seats and the aisle appeared to work for K-5 pupils but that many middle- and high-school pupils would find it difficult to walk the aisles and would not be able to sit appropriately in the seats. The row spacing would need to be increased for older pupils. This is consistent with ALSDE’s preference for maximum row spacing.

To gather additional information, phone interviews were conducted with four school systems in other states. All mandated seat belt use. The systems had deployed flex seats on fleets ranging from 5 to 113 school buses. Pupil ages ranged from three years to high school seniors. All four systems were purchasing additional flex-seat buses and two were adopting them for their entire fleets.

Two of the school systems reported high rates of use, around 90%. One reason may be that the belts easily accommodate elementary-school and high-school bodies. One system had a bus that ran two routes, with middle/high-school pupils dominant on the first route and elementary-school pupils dominant on the second route. Pupils had to reset and adjust their belts at the beginning of both routes, but it was easy enough that the young children could do it. These belts are good for multi-purpose buses.

In general, they purchased the longest school buses available and used a 3-2 seat combination. With minimum spacing between seats, they typically lost one bench seat on the driver’s side but none on the door side. For one system bus capacity dropped from 78 to 75; for another it dropped from 72 to 69; and a third reported no loss of capacity. All four systems acknowledged minimum row spacing was tight and could be a problem for tall pupils whose knees pressed into the seatback. All four said a 3-2 seat combination is necessary or it is too hard to go down the aisle. Higher seatbacks contribute to the difficulty of moving down the aisle because the side of the seatback flares away from the aisle at a higher point above the floor. The flex seats do not have as much flare slope as the existing type of seats.

All four school systems reported positive effects on discipline. One indicated that discipline issues cut in half and another reported a 95% drop. Pupils stayed in place better and could not hang into the aisle or hit other pupils with belt buckles. There is a ratchet device that keeps the belt snug and discourages twisting or leaning into the aisle. The belts improve both discipline and inappropriate use.

In summary, the video observations, ALSDE on-bus observers, and phone interviews suggest flex seats appear to offset all or part of the loss of capacity from installation of seat belts. All four out-of-state school systems had positive opinions of flex seats. All interviewees liked the seats, felt that they improved safety and discipline, and expressed that they were easy to adjust for different-sized pupils. All four school systems were purchasing additional buses with flex seats. However, to minimize capacity loss they all used extended buses, wider benches on one side of the aisle, and minimum (or near-minimum) row spacing. This should result in a loss of
three seats on one side of the bus, but one school system reported no loss of rows. The school systems also suggested that such spacing is challenging for big or tall pupils. (ALSDE has expressed a similar opinion.)

States desiring to keep full or near-full row spacing, like ALSDE, should count on losing six seats (an entire row) and perhaps nine seats with the installation of seat belts, depending upon the bus make and model ordered. If flex seats are adopted in Alabama, long buses should be ordered and wider seats on one sides of the aisle. At standard or near-standard spacing, the row/seat configurations would change from (3/3-12) to (3/3-11).

If ALSDE adopts maximum row spacing on the driver’s side of the bus and near-maximum row spacing on the door side of the bus, only one bench seat would be lost on one side of the bus. This falls halfway between the (3/3-12) and (3/3-11) configurations. Based on Table 3-6, that flex-seat configuration would result in slightly less that 10% of existing buses being overloaded (halfway between 3% and 16%). If ALDOT decides to use maximum row spacing on both sides of the bus, the capacity loss would approximate the 3/3-11 configuration.

3.4.2 Longer Passenger Compartments

There is possibly a second way to mitigate loss of capacity due to seat belts. If school bus manufacturers lengthen school bus seating compartments, the lost rows of seats might be restored. At least one manufacturer has indicated willingness. However, it would require lengthening the wheel base, making the bus more difficult to control and requiring a larger turning radius. This is a detriment to bus movement in small, crowded school areas and on narrow, crooked rural roads. Manufacturers must do additional research to determine the desirability of this option. At the same time individual school systems can examine their bus movements in school parking lots and on narrow rural roads. These analyses will indicate locations where a longer bus wheelbase would be detrimental to bus operations.

Taken together, installation of flex seats and use of longer bus chasses offer the possibility of restoring current capacity. However, the degree of local success will be linked to preferences and configuration decisions made by individual school systems when they specify and purchase school buses.
Section 4
Summary and Recommendations

4.1 Summary

This study is one component of the comprehensive Alabama School Bus Seat Belt Project. It was conducted to determine the impact of seat belts on school bus capacity. Specifically, the intent was to determine the percentage of buses with insufficient capacity to carry current pupil loads after installation of seat belts and to recommend strategies and fleet-size requirements for optimal utilization of school buses. The study was limited to type C and type D school buses with capacities ranging from 71 to 84 elementary-school pupils, which are typical in Alabama.

This is an important study because public momentum across the nation is shifting toward requiring seat belts on school buses and the potential loss of capacity is a burning issue among pupil transportation managers. Part of the Project was conducted to provide data to address this important issue.

4.1.1 Seats and Configurations Modified to Accommodate Seat Belts

Several manufacturers provide school bus seats equipped with seat belts. To accommodate the belts, these seats must be higher and stronger to position the belt correctly and to absorb large crash-impact forces. This makes seatbacks three to five inches thicker and causes the loss of one or more rows of seats. In addition, most seat belts have a fixed 15-inch width, which causes the loss of one seat per row. A bus might currently carry 72 elementary-school pupils with 12 rows with 3 seats on each side (3/3-12 configuration). Once seat belts are installed the seating might convert to a 3/2-11 configuration, resulting in a capacity of 55 elementary-school pupils.

4.1.2 Literature Review

Five prior studies considered school bus capacity after the installation of seat belts. NHTSA’s (2002) report to Congress estimated a 17% reduction in capacity. Similar studies were conducted in Indiana in 2005, in North Carolina in 2007, and in Texas in 2009. They estimated capacity reductions of 0 to 17%, 8 to 17%, and 16 to 33%. In addition, the four studies gave cost ranges from $2,440 to $14,000.

In 2007 the Congressional Research Service (CRS) reported that a manufacturer was producing a flex seat with a bottom belt anchor that slides sideways to accommodate either three elementary-school pupils or two older pupils. The flex seat might offset the loss of capacity.

4.1.3 Analysis of Alabama School Buses

The analysis of Alabama school buses was conducted using two datasets. The first data were taken from the annual Route Report submitted by school systems at the beginning of the school year. It provided an overall picture of the key issues and allowed a preliminary analysis of the
fleet, but it lacked specific information about the manufacturer’s stated capacity and pupil age distributions for individual buses, which prohibited a thorough analysis. UTCA researchers were able to deduce pupil ages for many but not all the buses.

Transportation supervisors provided more detailed data, including the manufacturer’s stated capacity and pupil ages. Since the optimal seat configuration has yet to be established for school bus seat belts, four seat configurations were analyzed. They represent the current seat and row arrangement (3/3-12); loss of a six-seat row (3/3-11); loss of one seat per row, or 12 seats (3/2-12); and loss of both a row of seats and one seat per row, or 17 seats (3/2-11).

UTCA researchers prepared software to test each school bus by placing its current pupil load on the four configurations. Pupil age was a key issue. A common rule of thumb is that three elementary-school pupils or two middle/high-school pupils can sit on the current bench seat on each side of the bus. A type C bus with the standard seat configuration has a capacity of 72 elementary-school pupils or 48 middle/high-school pupils. For a bus with a mixture of elementary and middle/high-school pupils, the capacity depends on the ratio of elementary to middle/high-school pupils. UTCA researchers created an equation to determine the capacity for each bus in the sample based on the current pupil loads. The results suggest additional buses would have to be purchased to carry existing pupil loads:

- 3/3-12 configuration: running with 3% of buses overloaded
- 3/3-11 configuration: 16% will lack sufficient capacity to carry its current pupil load
- 3/2-12 configuration: 7% will lack sufficient capacity to carry its current pupil load
- 3/2-11 configuration: 20% will lack sufficient capacity to carry its current pupil load

Since the base condition (current 3/3-12 configuration) represents as much as 2% error, UA researchers concluded that it was reasonable to reduce the over load percentages in Table 3-5 to 1%, 14.4%, 4.6% and 18% for the 3/3-12, 3/3-11, 3/2-12 and 3/3-11 configurations respectively.

The study anticipated that two older pupils (middle school or high school) could sit on the 30-inch-wide bench in 3-2 seating. While it is doubtful two large high-school pupils could sit on this seat, a driver can usually assign these seats to two smaller pupils.

### 4.1.4 Assessing the Accuracy of the Study

Two methods assessed the quality and accuracy of the findings. The first method compared the transportation-supervisor analysis with the Route Report analysis. The transportation-supervisor analysis was found to be better. In addition, although the absolute accuracy of the analysis could not be established and the calculated values included some error, careful data assessment led researchers to conclude that the error was less than 2%. The error could be due to clerical errors or padding of the reported number of pupils by bus drivers or transportation supervisors.

The second method compared overloads on individual buses to the theoretical maximum overload for the configuration under study. Once seat belts were installed, no configuration went beyond the theoretical maximum except the existing 3/3-12 (current configuration, overloaded by 3% as explained previously).
Taken together, the two assessment methods indicated that study results can be trusted.

4.1.5 Flex Seats and Longer Buses

There are two potential mechanisms to mitigate loss of capacity due to seat belts. The first is the flex seat. It has the potential to allow either three elementary- or two middle/high-school pupils to ride on either side of the bus. Video observations, phone interviews with school systems in other states, and a field observation visit all supported the same general conclusions: the seats work well and offset the loss of capacity brought using seat belts. However, flex seats are wider than the current seats and they squeeze aisle space, so seats must be wider on one side. Special precautions must also be taken with row spacing to accommodate middle/high-school pupils.

The second method is for school bus manufacturers to lengthen school bus seating compartments. However, this would require lengthening the wheel base, making the buses more difficult to control and requiring larger turning radii. This is a detriment to bus control in small school parking lots and narrow, crooked rural roads. Manufacturers and school systems can do additional research to determine the feasibility and desirability of this option.

4.1.6 Unique Contribution of this Study

This study makes two contributions to the knowledge of school bus capacity loses due to installation of seat belts. First, it provides a comprehensive literature review to determine the state of knowledge and to identify the major issues affecting capacity. Second, it is the first time that current pupil loads were tested on individual school buses for four seat/row configurations to determine the loss of capacity. Through careful assessment of the data, error was minimized and reasonable estimates were prepared for loss of capacity for the four potential configurations after installation of seat belts. In addition to these contributions, the study used video, on-bus observation, and a telephone survey of school systems using the seats.

4.2 Recommendations

This project quantified the effects of school bus seat belts on bus capacity for four configurations: three seats on each side of the aisle for 12 rows (3/3-12), three seats on both sides of the aisle for 11 rows (3/3-11), three seats on one side and two on the other for 12 rows (3/2-12), and three seats on one side and two on the other for 11 rows (3/2-11). These results can be extended to other configurations by interpolation. This study also estimated that the rate of overload would increase between 1 and 18 percent, based on configuration, if the buses tried to carry their current pupil load with seat belts.

Should school bus seat belts become mandatory in Alabama, local school systems can use this information to determine the optimal configuration for their pupils and the number of additional buses that must be purchased. Transportation supervisors can analyze their fleets to identify the seat configurations that best fit their pupil base. Then they can select bus manufacturers, models, and seating configurations that minimize loss of seating capacity while meeting their pupil transportation needs. Many of the buses that are overloaded due to seat belt installation will only
carry a few excess pupils. Transportation supervisors may be able to handle such overloads by transferring these pupils to other buses or by adjusting their bus routes.

Virtually all school systems will need to purchase buses to accommodate a seat belt requirement. The authors hope the results of this study will be useful in making those purchases wisely.
Section 5

References


Appendix A
Acknowledgments

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


