School Bus Crashworthiness Research

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NHTSA
October 2002

Outline

- Background
- Statistical Data
- Full-Scale Tests
- Sled Tests
- NAS Study
- Research Results
- Future Work

School Bus Facts

- 450,000 School buses (A, B, C, & D)
- 4.3 Billion miles traveled
- 23.5 Million children
- 8.5 Billion student trips
School Bus Types

A

- **Type “A”**
  - Constructed utilizing a cutaway front section vehicle with a left side driver’s door
  - Includes two classifications
    - Type A1, with a GVWR of 10,000 pounds or less
    - Type A2, with a GVWR greater than 10,000 pounds

B

- **Type “B”**
  - Constructed utilizing a stripped chassis
  - Entrance door is behind the front wheels
  - Includes two classifications
    - Type B1, with a GVWR of 10,000 pounds or less
    - Type B2, with a GVWR greater than 10,000 pounds

C

- **Type “C”**
  - Constructed utilizing a chassis with a hood and front fender assembly
  - Entrance door is ahead of the front wheels

D

- **Type “D”**
  - Constructed utilizing a stripped chassis
  - Entrance door is ahead of the front wheels
  - Also known as “Transit style” or “Forward control vehicle”
1999-2000 Sales by Bus Type

<table>
<thead>
<tr>
<th>Bus Type</th>
<th>1999 Sales</th>
<th>2000 Sales</th>
</tr>
</thead>
<tbody>
<tr>
<td>Type A</td>
<td>10,181</td>
<td>25,898</td>
</tr>
<tr>
<td>Type B</td>
<td>250</td>
<td>11,341</td>
</tr>
</tbody>
</table>

State Restraint Requirements

- New York - Currently requires lap belts (1987)
- New Jersey - Currently requires lap belts (1994)
- Florida - Currently requires a “safety belt” (which is a lap belt) (2001)
- Louisiana - Will require “occupant restraint systems” (June 30, 2004)
- California – Will require Lap/Shoulder belts
  - School buses (2005)
  - Small school buses (2004)

School Bus Research Plan

SCHOOL BUS Safety: Safe Passage for America’s Children

National Highway Traffic Safety Administration
Statistical Data

The National Automotive Sampling System
General Estimates System (NASS GES)

Statistical Data

SB Statistical Data

- School bus body vehicles
  - All school bus body vehicles, regardless of use
  - 1977 and newer (post-standard vehicles)
  - 11 Crash years – 1990 through 2000

School Bus Body Vehicles Summary

- ~26,000 Crashes per year
- ~10 SB Occupant fatalities/year
- ~9,500 SB occupant injuries/year

1990-2000
10.2 Fatalities per year
- 25% Drivers
- 75% Passengers

School related
- YES – 85%
- NO – 15%

School Bus Body Vehicles
Occupant Fatalities

1990-2000

55 Fatal passenger crashes
- 5 per year

83 Passenger fatalities
- 7.5 per year
  - ~6.0 for Full-sized school buses
  - ~1.5 for Van-based school bus

1990-2000

7.5 passenger fatalities per year
- ~2 Passenger fatalities in frontal crashes
  - Target for belts
- ~2 Passenger fatalities in side crashes
  - Typically in intrusion zone (includes trans)
- ~3.5 Include other crash and non-crash modes
  - Overtum (belts could help)
  - Rear
  - Non collision (such as, fell from vehicle)
### 01 School Transportation - Related Fatal Occupants

<table>
<thead>
<tr>
<th></th>
<th>Fatal Crashes</th>
<th>Fatalities</th>
</tr>
</thead>
<tbody>
<tr>
<td>School buses</td>
<td>8</td>
<td>4</td>
</tr>
<tr>
<td>Van-based SB</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>Veh used as SB</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>Total (Van &amp; Shuttle Bus)</td>
<td>12</td>
<td>6</td>
</tr>
</tbody>
</table>

- Source 2001 FARS Annual File

### 01 School Transportation - Related Fatal Passengers

- **10 SB passengers (school transport)**
  - Side intrusion by striking heavy trucks
    - 2 crashes, 4 passengers
  - Hit guardrail, over bridge rail, dropped 60 ft, overturn
    - 1 crash, 4 passengers
  - Intrusion into side of bus by snow plow blade that broke off plow
    - 1 passenger
  - Infant CSS incorrectly secured in vehicle
    - 1 passenger

- Source 2001 FARS Annual File

### 01 School Bus Fatal Crash - Arkansas

- NTSB
Vehicle Tests
- Full scale tests
  - Frontal
  - Side

Laboratory Tests
- Sled tests

Research conducted at NHTSA’s Vehicle Research and Test Center (VRTC)
- East Liberty, OH

Full Scale Tests
- Frontal barrier test
  - Class “C” SB
  - Flat barrier
  - Striking speed – 30 MPH

- Side impact test
  - Class “D” SB
  - Striking vehicle - 22,265-lb truck
  - Striking speed – 45 mph
  - Angle - 90 degrees
  - Impact point – Left side just behind front tires on bus
Frontal Barrier Test
Post Crash Photo

Side Impact Test
Pre Crash Photo

Side Impact Test
Occupant Seating Position

1 - Hybrid 8th Grade Male
2 - Hybrid 8th Grade Male
3 - Hybrid 8th Grade Male
4 - Hybrid 8th Grade Female
5 - Hybrid 8th Grade Male
6 - Hybrid 8th Grade Male
7 - Hybrid 8th Grade Female
8 - Hybrid 8th Grade Male (Balloon)
9 - Hybrid 8th Grade Male (Galvanic)
Side Impact Test - Video

Side Impact Test Post Crash Photo

Laboratory Testing

- 3 Series
  - Buck fabricated from SB
  - Generic (Flat plate) buck
  - Recent tests

- Hi severity
  - 35-37 mph
**Generic (Flat Plate) Buck**

**Restraint Systems Evaluated**
- Compartmentalization
- Lap belts
- Lap/shoulder belts
- New systems

**Occupant Sizes**
- **Small-sized student**
  - 6 year-old dummy
  - 52 lbs
- **Medium-sized**
  - 12 year-old
  - 50th percentile female dummy
  - 108 lbs
- **Large high school student**
  - 50th percentile male dummy
  - 172 lbs
Injury Assessments

- Head Injury Criteria (HIC)
- Neck injury criteria (Nij)
- Chest injury criteria (G's)
- Leg injury criteria (Femur load)
- Abdominal loads
  - experimental measurement systems

Restraint Operation

Compartmentalization

Blue Bird Bus Seats
Seat Back Height Issue

50th Male into Standard Height Seat

50th Male into Standard Height Seat w/ 5th Female in Front
Test Results

HIC by Restraint

Head Injury

Compart. | Lap Belt | LS Belts | LS-misuse 1 | LS-misuse 2
---|---|---|---|---
6 Year Old | 5th Female | 50th Male
### Neck Injury

![Bar chart showing neck injury by restraint type for different age groups and gender categories.](image)

- **6 Year Old**: Lap Belt, L/S Belts, L/S misuse 1, L/S misuse 2
- **50th Male**: Lap Belt, L/S Belts, L/S misuse 1, L/S misuse 2

### Chest Injury

![Bar chart showing chest injury by restraint type for different age groups and gender categories.](image)

- **6 Year Old**: Lap Belt, L/S Belts
- **5th Female**: Lap Belt, L/S Belts

### Peak Load - Abdominal Area

<table>
<thead>
<tr>
<th>Dummy</th>
<th>Restraint</th>
<th>Load</th>
</tr>
</thead>
<tbody>
<tr>
<td>6-Year-Old</td>
<td>Compartmentalization</td>
<td>100 lbs (444 N)</td>
</tr>
<tr>
<td></td>
<td>Lap belt only</td>
<td>291 lbs (1,293 N)</td>
</tr>
<tr>
<td></td>
<td>Lap/shoulder belt</td>
<td>164 lbs (729 N)</td>
</tr>
<tr>
<td>5th Percentile Female</td>
<td>Compartmentalization</td>
<td>135 lbs (601 N)</td>
</tr>
<tr>
<td></td>
<td>Lap belt only</td>
<td>768 lbs (3,371 N)</td>
</tr>
<tr>
<td></td>
<td>Lap/shoulder belt</td>
<td>308 lbs (1,372 N)</td>
</tr>
</tbody>
</table>
Conclusions from Data

Compartmentalization

- Low head injury values
- Medium neck injury values
- Seat back override in extreme conditions

Lap Belts

- Low head injury values
- High neck injury values
  - Nij higher than compartmentalization restraint
- Keeps passengers in their seats
Lap/Shoulder Belts

- Low head injury values
  - Lower than compartmentalization and lap belt results
- Low neck injuries values
  - Less than other restraints
- Keeps passengers in their seats
- Restraint misuse can produce undesirable outcomes
  - Becomes lap-belt-only like
- Stiffer seat back possibly needed
  - Could affect unbelted occupants behind

Report to Congress and News Release

Report to Congress

- April 2002
- Abstract
- Downloadable copy of full report
- Downloadable movies
News Release


- NHTSA 37-02
- May 7, 2002

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Agency is considering the following changes to existing federal safety regulations:

- Increase seat back height from 20 inches to 24 inches
- Require buses under 10,000 pounds to have lap/shoulder restraints
- Develop standardized test procedures for voluntarily installed lap/shoulder belts

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National Academy of Sciences
The Relative Risks of School Travel: A National Perspective and Guidance for Local Community Assessment

Special Report 269 (2002)

Sponsored by NHTSA

Performed by the National Research Council

Purpose: To help identify the risks of school travel

The report considered six transportation modes of traveling to and from school:
- School buses
- Transit buses
- Motorcoach services
- Passenger vehicles driven by individuals 19 or older
- Passenger vehicles driven by operators under 19 YO
- Pedestrians and bicyclists

Every year, about 800 school-age children are killed in motor vehicle crashes during normal school travel hours – weekday mornings and afternoons during school months.

These fatalities account for about 14 percent of the 5,600 child deaths that occur on the nation’s roadways.

Children are at far more risk traveling to and from school in private passenger vehicles – especially if a teen-age driver is involved – than in school buses.

Bicycling and walking also place students at greater risk than traveling by school bus.
NAS Report - Findings

- Of these 800 deaths
  - Most (~74 percent) occur in private passenger vehicles
  - More than half of all the child fatalities occur when a teenager is driving
  - Many (~22 percent) are the result of pedestrian or bicycle accidents
  - Very few (~2 percent) are school-bus related

NAS Report

- Detailed recommendations
- Copies of this report is available at:
  www.nap.edu


Additional Research
Research Plan

- VRTC – Testing Additional Restraint Systems
- VRTC – Side Impact Protection
- Mercer University’s Engineering Research Center

VRTC Testing Completed

- Testing Additional Restraint Systems
  - 3-point seat – multi part seat system
  - Inflatable restraint system
- Side Impact Work
  - In progress
  - Looking at head impacts

3-Point Seat System

- I-M-M-I
- Integrated seat incorporating a three point (lap/shoulder) belt restraint system
- Protection for both belted and unbelted occupants
- Provides unique solution to this design/safety issue
Air Bag System

- AMSAFE Safety Restraint System
  - Developed for use on airline passenger seats
  - Bag shape and volume fine tuned for school bus application
  - Installed in the webbing of the lap belt and deploys forward and upward into the space of the wearer and the seat back in front

- Similar criteria response levels to those sled tests involving the lap/shoulder belt configuration

- Not Evaluated
  - Out of position occupants
  - Effects of objects in the occupants lap
Safe-T-Bar

- Manufactured by The Majestic Companies, Ltd.
- Similar in concept to the lap bars frequently used in amusement park rides
- Padded bar rests on (or near) the lap of the occupant and locks in place during a crash
- It is not an appropriate restraint for higher severity environments

Safe-T-Bar

Mercer University’s Engineering Research Center

- Developing a finite element model of a typical school bus construction
- Studying the effects of sidewall padding on occupant protection
- Developing a finite element model countermeasure to address side impact excursion
- Considerations are being given to the effect of seat pad contours and other parameters. The effectiveness of restraint systems for various size occupants is being assessed
Further Work and Documentation

- ESV Report on SB research (5/03)
- Complete and document MERC’s research and findings
- Complete side impact head injury research

NHTSA SB Team

- This presentation brought to you by:
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