WHY SEATBELTS SHOULD NOT BE INSTALLED ON LARGE SCHOOL BUSES

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INTRODUCTION

Particularly since 1967, considerable research has been conducted in the United States on the subject of seat belts on school buses, much of it in response to the proven safety benefits of seat belts installed in a range of other passenger vehicles. This research—including several crash-testing projects designed specifically to examine the benefits and drawbacks of seat belts on school buses—suggests strongly that the problems from the installation and use of the technology outweigh their benefits.

Essentially, seat belts limit passenger movement immediately before, during and following a collision, preventing ejection and minimizing post-crash "rebounding" within the vehicle. In school buses, these impacts are already suppressed to a great degree by seat "compartmentalization," which minimizes rebounding and makes ejection a rarity. Further, seat belt technology conflicts with, and compromises the benefits of, other school bus technologies and features designed to protect passengers, as discussed in the sections below.

Because the problems seat belts create are so interrelated, they are extremely complex. These problems integrate considerations of physics and laws of motion with variables among restraint systems, vehicle construction, passenger size, belt usage and a number of other dissimilar factors. As an illustration of this complexity, the installation of dozens of seat belts would greatly increase the g-forces exerted on the bus floor. This added stress would not likely increase the rare tendency of schoolbus bodies to separate from their chassis, since the loads from belted passengers would occur as a "secondary" crash pulse, a fraction of a second after the bus collides and has stopped (or is skidding to a stop).[1] However, because of a large school bus's unique construction, seat-belted passengers could experience dramatically different consequences than unbelted passengers:

- If the belts were fastened ***to*** the floor (i.e., attached to the **body**), the secondary crash pulse could conceivably rip seat anchorages from the floor (pp. 25, 126, 127 CHP/SRI, 1977 and pp. 126, 127, Transport Canada, 1984) or otherwise pull the seats apart (p. 10, NHTSA, 1985). This is unlikely to happen in most school buses today since the required seat anchorage strengths were increased by NHTSA, several years ago, to accommodate 5,000 pound loads ***per seatbelt position*** at each anchorage point (FMVSS #209, Seat Belt Assemblies and FMVSS #210, Seat Belt Assembly Anchorages). Nevertheless, the loads exerted on seat anchorages from the combined weight of two or three strapped-in passengers plus the seat would be ***far*** greater than those exerted by a 60- or 70-lb. seat bench itself (were the passengers not attached to it). Were the seat to leave its moorings,

[1] These separations occurred in the Palm Springs (1991) and Fox River Grove (1995) accidents and UCLA (1967) and Transport Canada (1984) studies.

its belted passengers would accompany it--and likely incur more serious injury as part of this "module" than they would in individual flight (p 29, CUTR, 1993).

- Were the belts fastened ***through*** the floor (i.e., to **chassis** frame members), the rare separation of bus body from chassis would permit the belts to stretch and twist the passengers severely, possibly tearing them apart.

Without seatbelts, the energy from this secondary crash pulse would simply be absorbed by the seatbacks in front of each passenger (and to some degree, of course, by the passengers' bodies). With unbelted passengers, these forces would not likely be sufficient to tear the seats from the floor. These forces would be much greater with passengers attached to their seats.

While past crash-test studies and accident experiences shed light on these scenarios, it is clear that additional research is needed to draw firm conclusions about them. Such lessons would be far better learned through engineering analyses and testing than from actual experience.

Apart from a schoolbus's structural and design characteristics, one must also not overlook its other physical attributes and operating environment, both of which provide a context for examining seat belt feasibility. One notable advantage is its mass and structural configuration with respect to the size and shape of other objects with which it would likely collide. Because fatalities are inversely proportional to the relative mass of colliding vehicles, at a sharply geometric scale (masses of 2:1 yield fatalities of 1:7), a 37,000-lb. school bus will fare well against a 3,000-lb. automobile (p. 3-19, CHP, 1987). And a school bus's high floor and bumper alignment tend to funnel a typical car beneath the passenger compartment, permitting the bus chassis to absorb much of the impact. Vehicles likely to impact with ***equal*** or ***greater*** forces (e.g., an airplane hitting the ground), where ejection is likely, commonly **include seatbelts**. Those likely to impact with much ***smaller*** forces (e.g., a bus or train hitting a car), where ejection and rollover are far less likely, typically **do not**. Arguments for including or excluding seat belts in school buses should mirror the logic of installing them in a ***range*** of vehicle types. Analogies made solely to automobiles do not present a fair and accurate comparison to vehicles within this spectrum, nor draw the necessary logic from their experiences. As NTSB Report #56 points out, "no lap belt effectiveness estimates from analysis of non-school bus vehicles are necessarily valid for schoolbuses" (National Transportation Safety Board: "Safety Study—Crash Worthiness of Large Post Standard School buses." Report NTSB/SS-87-01 (NTIS No. PR87-917002), Washington, D.C.).

From an operating perspective, school buses have also been afforded a number of significant and often unique safety advantages:

- To enhance conspicuity, schoolbuses are painted a distinct color, and motorists are not permitted to pass them while they load or unload passengers (not even in the opposite direction when the road is not divided).

- School buses have special equipment to attract attention to their presence during loading and unloading--such as flashing light systems, swing-out stop arms and, in many states, crossing gates (to prevent students from crossing too closely in front of the bus where the driver may not see them).

- In almost all states (New York and Connecticut excepted), students are not allowed to ride standing. All passengers must be seated before the vehicle even begins moving.

MAJOR TESTING, RESEARCH AND STUDIES

While a considerable number of policy statements, opinions and perspectives have been authored on the subject of seatbelts on school buses, the conclusions drawn in this analysis were based largely on the results of crash-testing experiments and related studies. The most important of these included:

- School Bus Passenger Protection: Institute of Transportation and Traffic Engineering, University of California, Los Angeles, by Severy, Derwyn M.; Brink, Harrison M.; and Baird, Jack D. (Los Angeles, CA 1967).

- A Study Relating to Seat Belts for Use in Buses: Prepared for the California Highway Patrol by the Southwest Research Institute, by Ursell, C.R. (Sacramento, CA, 1977).

- Safety Study—Crashworthiness of Large Poststandard School Buses: National Transportation Safety Board, Bureau of Safety Programs (Washington, D.C., 1987).

- School Bus Passenger Seat and Lap Belt Sled Tests: National Highway Traffic Safety Administration, U.S. Department of Transportation, by Bayer, A.R. (Washington, D.C. 1978).

- Possibilities of Development in Bus Safety: TÖV Rheinland Institute for Traffic Safety, by Rompe, Klaus and Kroger, Joachim H. (Cologne, Federal Republic of Germany, 1984).

- School Bus Safety Study: Transport Canada, Traffic Safety Standards and Research, Crashworthiness Section, by Farr, G.N. (Quebec City, Quebec, Canada, 1984).

- School Bus Seat Belt Study: Booz, Allen & Hamilton, Inc., submitted to the California Highway Patrol, Motor Carrier Section (Sacramento, CA 1987).

- Florida School Bus Occupant Safety: Center for Urban Transportation Research, College of Engineering, University of South Florida, by Baltes, Michael R. et. al (Tampa, FL 1993).

- Safety Belts in School Buses: National Highway Traffic Safety Administration; U.S. Department of Transportation, Washington, D.C., 1985).

The arguments for not including seat belts in school buses, cited below, are separated into five categories for organizational purposes:

- Seats and Seating Systems
- Types of Restraint Systems
- Passenger Considerations and Characteristics
- Other Technical Considerations
- Institutional Considerations

In reality, the interrelationships of variables both within and among these categories is considerable (pp. 1-1, 3-14, 3-15, 3-16, CHP, 1987). To extract the most accurate meaning from the points in each category, and minimize the degree to which they are misapplied or overextended, each point should be considered in the overall context of the full range of variables. Further, the applicability of these conclusions is limited only to large Type C and D school buses, not to Type A and B school buses constructed on "cutaway" chassis, for which the installation and use of seat belts is far more appropriate and, as such, **required**.

SEATS AND SEATING SYSTEMS

No single type of seat belt system is appropriate for all school buses or all passengers because of differences in the seating systems and seat characteristics of various types and sizes of school buses:

- While all compartmentalized school bus seats meet strict uniform standards (Federal Motor Vehicle Safety Standard #222: School Bus Passenger Seating and Crash Protection), there are subtle differences in seat type, design, structure, materials and spacing from state to state and bus to bus (pp. 292-295, UCLA, 1967). These differences exist in seat stiffness and range of motion, seat pitch, densities and deformation characteristics of seat padding materials, deformation properties of seat structures, and the space between seats and seatbacks (pp. 28, 84, 85 CHP/SRI, 1977).

- Seat back heights vary among states and school districts (24 inches in most, 28 inches in New York State). The motion of a belted passenger (particularly if only a lap belt is used) is considerably different when the seat back is 24 compared to 28 inches high. With a 24-inch seat back height, the lap belt accelerates the movement of the passenger's head into the upper edge of the seat back directly in front, rather than into the inclined surface of the higher seat back, significantly increasing the possibility of severe facial, head, neck and spinal injury. (This difference in heights would not affect a smaller child whose head could not reach the upper edge of even the lower seat back. However, the lap belt would accelerate such a child's head into his or her knees.)

- While seat spacing or "crush distances" between school bus seats may be ideal for compartmentalized seats, it is far too close to accommodate seat belts. Both the Transport Canada and FRG/TÖV Rheinland studies found the optimum distance between seats equipped with seat belts to lie between 31 and 35 inches. The CHP, 1987 study (pp. 3-8) found it to be even greater. In contrast, compartmentalized school bus seats lie only 24 to 25 inches apart. Because this distance is less than the “envelope” of restraint provided by the belts, the belts would appear to serve no purpose: Passengers would strike the seatbacks before the belts could restrain their movement (p. 3-18, CHP, 1987).

  But the conflict between belts and this spacing creates far worse problems. Knee clearance and the impact strength of seat backs also influence the equation. With closely spaced, compartmentalized seating, the passenger's knee strikes the seat back first in a frontal collision and acts as a fulcrum to accelerate his or her head into the seat back directly in front (p. 324, UCLA, 1967; p. 4, CHP/SRI, 1977; pp. 49, 58, 61, Transport Canada, 1984; p. 7, NHTSA, 1985; p ix, CUTR, 1993). Seat material densities have been designed to cushion passengers from this impact and absorb the acceleration forces (FMVSS #222). However, when seat belts (particularly lap belts) are employed, they replace the knee as a fulcrum with the passenger's waist. Because the waist is already lying against the seat belt prior to impact, this fulcrum accelerates the passenger's head forward into the seat back in front at a much higher rate, significantly increasing the potential for serious injury (p. 324, UCLA, 1967; p. 6, Transport Canada, 1984; p. 7, NHTSA, 1985; p. 3-18, CHP, 1987).

  This conflict is complicated further by the fact that compartmentalized seats were designed to accommodate this knee-to-head sequence (FMVSS #222): Foam densities differ in the upper part of the seat back (where the head would strike) compared to the lower part (where the knee would strike). Imposition of a seat belt would naturally change the trajectory of a passenger’s body striking the seatback in front. As a consequence, unless the spacing between seats were increased considerably (as per the comment above), seatbacks would have to be completely redesigned to accommodate seatbelts. Ergo, retrofitting a bus with seatbelts **would also mean retrofitting its seats as well** (p. 327, UCLA, 1967).

  From the limited experience of seat belts on full-size school buses, the combination of compartmentalized seats and seatbelts does not appear to exhibit, in practice, the problems which exist in theory. These experiences (in New York and New Jersey), and extensive experiences with seatbelts and closely-spaced compartmentalized seats on smaller Type A and B schoolbuses, suggest that seatbelts may have an additive value to compartmentalized seats (most importantly, by preventing ejection)—at least to the degree each technology’s benefits could be isolated in accident investigations where these technologies prevented or minimized fatalities and/or injuries. The NHTSA study currently underway will hopefully provide insight on this point.

- Seat anchorage systems are generally not designed to accommodate the forces exerted on them were passengers belted into seats (pp. 126, 127, Transport Canada, 1984). As noted, recent NHTSA regulations (FMVSS #209, #210) increased anchorage strengths to accommodate seatbelts—requiring anchorage points to withstand 5,000 pound loads per seatbelt. Nevertheless, a range of anchorage types (bolts, cables, etc.) and positions (floor, sidewall, etc.) are employed (p. 46, CHP/SRI, 1977), and the effectiveness of these variables has not been tested with respect to the different levels and directions of pull which could be exerted on them in various accident scenarios, much less by passengers of different sizes and weights. Were such testing conducted, it is conceivable that its results would suggest that anchorages should be modified even further to withstand the increased and varying loads from belted passengers and diverse accident scenarios. Retrofitting such anchorage systems to existing buses—in effect, accessing hundreds of points beneath the bus floor--would be extremely costly and difficult, if not impossible in some cases (pp. 29-31, CHP/SRI, 1977).

- Seat anchorage positions also differ among buses (pp. 11, 85, CHP/SRI, 1977). All four legs (or both "U-braces") of some seats (e.g., some "special education" buses, near emergency exits, 2+3 seating combinations) are attached to the bus floor, while most seats (e.g., most large post-1977 buses) are attached to the sidewall (on the window side) and floor (on the aisle side). As a result, all seats do not react in the same way to impact forces. With the addition of belted-in passengers, the behavioral differences among these attachment approaches will be exaggerated in a collision.

- The motion of passengers restrained by seat belts is different for bench seats than for those with arm rests or other hip support devices (e.g., bucket seats). Because school buses employ bench seats, seat belts limit but do not prevent lateral motion (particularly in severe in side-impact or oblique-angle collisions) and, in many cases, may increase the severity of injury as passengers twist or rotate following a collision. And without hip support, multiple secondary movements or "rebounds" are modified and exaggerated by the belt, even though the range of movement is obviously more limited. These rebounds vary considerably depending on the type of belt, type and size of passenger, and other variables.

As a final comment, it must be noted that FMVSS requirements are ***performance*** standards, not ***design*** standards. The introduction of seat belts to the safety equation blurs these two notions considerably, since the performance impacts of seat belts have widespread implications for the design of other school bus elements—extending even to its structure. Proponents of seatbelts must, at least, acknowledge that to install seat belts ***optimally*** is no simple task. Given the complexity of adjusting so many other variables to accommodate seatbelts, their installation invites errors which could undermine their effectiveness even beyond those endemic to the technology itself (as described in this document). As school bus accidents illustrate repeatedly, engineering analysis and testing have their limits. The transition from compartmentalization to a system where seatbelt technology and all surrounding elements are ***optimized*** could come at the expense of some passengers' lives.

One must question the wisdom of incurring such costs when one considers how few lives are lost each year with the safety technologies currently employed by schoolbuses. This point would suggest proceeding with caution even if seat belt technology held the promise of improved safety. Since it does not appear to hold any such promise, proceeding to install seatbelt technology on schoolbuses without a fresh and thorough examination of the issues raised in this document, among others, would seem risky, at best. Fortunately, NHSTA is currently undertaking what promises to be such a study.

TYPES OF RESTRAINT SYSTEMS

As with seats and seating systems, various types of restraints and restraint systems create different benefits and problems:

- With the close seat spacing and 24-inch seat back heights of most school buses, testing experiences have repeatedly concluded that lap belts (i.e., without shoulder harnesses) **are far more dangerous than no belts at all** (pp. 325, 371 UCLA, 1967; p. 2, Transport Canada, 1984; pp. 54, 82, CHP/SRI, 1977). While three-point belts (i.e., including a shoulder harness) are far superior, they create special types of problems, particularly during secondary recoils and in side impact collisions where they can lacerate, sprain or even break a passenger's neck and, in rare cases, strangle the passenger (p. 373, UCLA, 1967; p. 6, CHP/SRI, 1977). If seat spacing is increased, lap belts will simply accelerate movement of the passenger's head into his or her knee (p. 344, UCLA, 1967). More than 200 tests have demonstrated that lap belts provide no protection from head injuries and, in many accident scenarios, make the injuries more severe (p. 3-13, CHP, 1987). In most front impact collisions, the chest accelerates forward faster than the vehicle; constraint by a lap belt increases this acceleration (p. 371, UCLA, 1967; p. 4, CHP/SRI, 1977; p. 3-12, CHP, 1987). And while 3-point belts do not exhibit the same problems as lap belts, one must acknowledge that, to date, no lap/shoulder belt combination has been proven to be technically feasible for school buses.

- While four-point belts (a lap belt plus two diagonal shoulder harnesses) address these problems in most cases, provide a degree of hip support, and reduce post-impact secondary rotations and rebounding, passengers have difficulty strapping themselves into them. This problem would create travel delays since, in most states, school buses are not permitted to move until all passengers are seated (and, if so equipped, with seat belts secured in place). There are far more serious concerns about vehicle evacuation with such belt systems. And the value of and benefits from four-point belts, like other solutions, obviously correlates highly with accident orientation (i.e., angle of vehicle impact) as well as passenger size.

- A three-point belt's level of attachment to the passenger's shoulder also affects the operation of the seat belt (p. 373, UCLA, 1967; p. 6, CHP/SRI, 1977). If the attachment point is too high or the passenger too small, he or she may slide under it following a frontal or side impact collision, possibly choking the passenger or spraining or lacerating his or her neck. If the attachment point is too low or the passenger too tall, the shoulder harness may squeeze the passenger's stomach and crush his or her internal organs (p. 77, CHP/SRI, 1977; p. 3-13, CHP, 1987). The common mixing of passengers of different sizes on a single bench seat complicates the task of addressing this problem: How can one install, much less enforce the proper usage of, an adjustable attachment point?

- Restraint system attachment points to the vehicle interior also vary considerably (p. 46, CHP/SRI, 1976), and affect the forces which the restraint system, attachment points and vehicle structure can withstand, as well as the forces to which various body parts are exposed. Restraint systems may be attached to the seat back, seat cushion, seat frame, bus floor or a chassis frame member. Because the bus chassis and body may separate in rare instances, certain combinations of attachment arrangements (e.g., belts anchored to chassis frame members with seats anchored to the floor) could effectively pull passengers apart or cut them in half. In contrast, other arrangements (e.g., seat belts anchored to the floor or the seat unit) would simply increase the g-forces on the seat and, in rare cases, launch it from its moorings. Retrofitting seat belts could compound this problem, as attachment choices may be more limited (as access to structural elements is more difficult) or unavailable.

- The fit of the belt and its slack affect the range of body motion it limits, the strain against body parts and, as a result, the safety benefits and problems it creates for every type and size of passenger.

- Belt width and material strength affect the degree of trauma to those body parts with which the belt comes in contact (p. 29, CHP/SRI, 1977). The wider the belt, the more impact forces are distributed over larger areas of the body and, consequently, the less trauma to the passenger's waist, neck, thorax and spine. At the moment, this variable is defined, as seat belt width and strength are defined by FMVSS #209: Seat Belt Assemblies. But even this required width has different effects on passengers of different size and age.

- Flexing and stretching characteristics of belt materials also differ greatly, affecting the degree to which they inhibit movement and the impact forces to which various body parts are exposed (p. 3-17, CHP, 1987). And even if their initial strengths are clearly defined (as per FMVSS #209), belt materials tend to stretch over time. As a result, the characteristics of the seat belt system tend to evolve as belts are constantly subjected to low levels of force **each time the vehicle stops.**

- Belt buckle loadings are also important variables (pp. 5,6, CHP/SRI, 1977). Some buckles may not withstand high speed frontal impacts well, especially with larger passengers whose weight increases the loads on the belts and buckles. In worst case scenarios, buckles could jam on impact, preventing passengers from evacuating the vehicle following a collision. Because belt buckle loadings are established by FMVSS #209 (subsequent to when most school bus seat belt research was conducted), buckle overloading is not likely to be a problem—although students jamming (with chewing gum, etc.), breaking and removing them were found to be a serious problem in the CHP/SRI study (1977).

- Despite the unlikelihood of buckles jamming, their simple release in certain catastrophic accidents (and perhaps even in serious, non-catastrophic accidents) could present evacuation problems, particularly for younger passengers—although limited experience in rollover accidents has demonstrated the opposite (P. 15, NHTSA, 1985). Ironically, the "carryover effect" which seat belt proponents cite as an advantage of school bus application could easily work against the students in such accidents (Gardner et. al, 1986: School Bus Safety Belts: Their Use, Carryover Effects and Administrative Issues. Office of Driver and Pedestrian Research, National Highway Traffic Safety Administration, Washington, D.C.), since release mechanisms—like the buckles themselves—are hardly standardized among passenger cars, even if they were standardized for all school buses: In a moment of panic, a child's instinctive "release response" might be appropriate for the buckle on the family car--**while not appropriate for the buckle variation employed on the school bus**

PASSENGER CONSIDERATIONS AND CHARACTERISTICS

Serious problems with seat belts exist because of the enormous variation among passengers. While these problems occur with seat belts used in other types of vehicles, the tradeoffs are far more acceptable where seats are not compartmentalized and, as a result, **belts are needed to prevent ejection and constrain rebounding.**

- All passengers are not the same size, age, height and weight. Even sexual differences affect the ability of the body to withstand the forces exerted on certain body parts by seat belt systems (p. 3-10, CHP, 1987). In particular, younger children's heads and thoraxes are more flexible and weaker than those of older children; their internal organs are exposed to impact forces from the seat belts which they cannot tolerate, resulting in internal injuries (p. 77, CHP/SRI, 1977; p. 3-13, CHP, 1987). In several automobile accidents, seat-belted school-age children who suffered no external injuries following severe collisions bled to death as their internal organs were crushed by the forces exerted on them by the belts.

- Even among passengers of the same height and weight, significant differences exist in body strength, tissue composition (e.g., percentages of muscle and fat) and flexibility. Therefore, some passengers can withstand the impact forces from certain types of seat belts better than others. And this may vary with the type of collision and impact speeds involved.

- Among all variations in body strength, the pliability of the abdomen is the most critical. While seat belts (including three-point belts) are designed to funnel the loads into the pelvic bone, this does not occur consistently, particularly with smaller children. Instead, forces are often focused on the abdomen. The abdomens of younger passengers, in particular, are not considered strong enough to withstand these forces and adequately protect their internal organs from serious trauma (p. 46, CHP/SRI, 1977; p. 3-12, CHP, 1987; and Dejammes, M. (Laboratories des Chocs et de Biomechanique, Born, France); "Lower Abdoman and Pelvis: Kinematics, Tolerance Levels and Injury Criteria" in Biomechanics of Impact Trauma Conference Proceedings, May, 1983, International Center for Transportation Studies, Amalfi, Italy, B. Aldman and A. Chapon (Editors), Elsevier, Amsterdam, 1984). In cases where small children slip or "submarine" beneath their seat belts, lower abdomens may compress the viscera against the lumbar spine, injuring the digestive tract. As a result, impact forces on the stomach are distributed in all directions, tearing apart internal organs in the process (p. 77, CHP/SRI, 1977).

- The passenger's degree and type of motion following the impact affects the degree and type of injury the passenger will suffer. This motion includes jackknifing, submarining, rebounding, torso rotation, whiplash, tossing and ejection. Depending on how these variations combine with different accident scenarios, **seat belts will often cause or worsen passenger injuries.**

OTHER TECHNICAL CONSIDERATIONS

A wide spectrum of technical considerations influence the effectiveness of seat belts on school buses, encompassing a number of vehicle, passenger and motion variables. The diversity of these considerations makes it difficult to place them in groups or categories:

- The comparative types, sizes and masses of the vehicles involved in a collision affect the degree to which impact forces are distributed between or among them. And the longer the bus, the greater the "columnization" or longitudinal collapse (p. 332, UCLA, 1967).

- Floor structure and composition are particularly important, especially in those rare instances where bus bodies separate from their chassis (UCLA, 1967; Transport Canada, 1984). As this occurs, floors buckle, accelerating the movement of passengers against the seat backs in front of them and other objects within the bus (p. 314, UCLA, 1967; p. 25, CHP/SRI, 1977). The variation in floor strength among school buses is considerable insofar as its ability to support loads from impact forces (pp. 12, 27, 28, 85, CHP/SRI, 1977; p. 3-17, CHP, 1987).

- Collision orientation (or impact mode) greatly affects the benefits from, and problems created by, seat belts. Five basic impact modes can occur: frontal, side, rear, rollover and oblique. Each results in different problems for each type of seat belt. For example, three-point belt systems cause many neck injuries in side impact crashes while they provide far more protection in front impact collisions. Seat belts of any type provide no discernible benefits in rear impact collisions, and generally increase the severity of injury from side or oblique angle collisions. Similarly, compartmentalized seats were designed to provide protection in frontal impacts, not side or oblique crashes.

- These tradeoffs must be weighed against the frequency of each type of collision orientation and the severity of injury which results from them. As an illustration, seat belts provide the greatest benefits in minimizing injuries in rollover accidents. However, rollover accidents are extremely rare. After rollovers, seat belts provide greater benefits in front impact crashes. Again, these are far more rare than rear or side impact collisions. Examining accident frequency against severity of injury demonstrates clearly that **the accident modes in which seat belts would likely provide the most benefits occur least often, while the accident modes in which they are either useless or harmful occur most often** (pp. 1-3, 2-4, 5-1, 5-2, CHP, 1987). As G.M. McKay pointed out in a 1978 London study: Safety Criteria in Vehicle Design (Institution of Mechanical Design), "…lap belts are successful in preventing ejection but do little else."

- The strength and reliability of structural elements within the passenger compartment (tubing, etc.), their structural deformation characteristics, and the number and type of interior obstructions all influence the consequences of rebounding, and the need for and importance of seat belts (p. 37, Transport Canada, 1984). If these elements remain in position following a severe collision, there is less danger that injury will occur to unbelted passengers striking them. Of course, serious injury can occur when passengers strike one another in a collision. However, compartmentalization greatly limits such movement so that passengers do not strike one another nearly as frequently or as severely. And even three-point seat belts will not prevent the heads of adjacent passengers from striking one another in many types of collisions (especially given the bench seats), particularly as almost all collisions cause passenger rebounding or secondary movement in directions other than that of the initial impact.

- Apart from bumper and frame misalignment (p. 329, UCLA, 1967), a vehicle's stiffness affects the degree to which another vehicle can penetrate it upon collision (pp. 3-11, 3-22, CHP, 1987). The point at which the bus is struck by the other vehicle is also critical, and affects the degree of intrusion (p. 3-11, CHP, 1987). Where intrusion is less likely, the potential for injury lessens and, as a result, the need to be restrained in one's seat is also less important (p. 3-23, CHP, 1987).

- A passenger's proximity to the point of impact affects the level of impact force to which he or she is exposed (pp. 304, 333, UCLA, 1967). In a large bus, most passengers would be seated several meters away from the point of impact in any collision orientation. Analyses of recent school bus accidents (e.g., Fox River Grove) suggest that the presence of seatbelts would not likely have helped those passengers seated at or near the point of impact. In contrast, seatbelts would likely hinder evacuation or—as was the case with the Fox River Grove accident—would impede many passengers' abilities to reposition themselves in the bus as far from the impact area as possible, as they see the colliding vehicle moving toward them.

- The ability of interior vehicle walls, surfaces, windows and structures to absorb impact forces is an important consideration. Heavily-padded, compartmentalized seats and padded crash barriers in front of the first row of seats are designed to minimize the exposure of passengers to these surfaces.

- To the degree they are included, seat belt retractor devices would be exposed to vandalism and theft and may require constant repair or replacement (p. 14, CHP/SRI, 1976; p. 46, Transport Canada, 1984). And they require continuous maintenance and cleaning. Conversely, the absence of retractors provides opportunities for aisle-side belts to be strewn across the aisles, posing a hazard to passengers approaching or leaving their seats. This problem could have severe multiplier effects in evacuation scenarios, where passengers are far less likely to be concerned with safe belt storage, and far less aware of obstacles in their path (p. 15, NHTSA, 1985).

- The dangers associated with both seat belts and their retractor devices expose passengers to injury and, as a result, may increase the costs of liability insurance, as might the misuse of buckles as weapons.

INSTITUTIONAL CONSIDERATIONS

In addition to the many technical issues related to seat belts in school buses, a wide range of institutional considerations compromise the benefits which seat belts might otherwise provide:

- A serious reduction in vehicle capacity will result from the need to increase spacing between seats by almost 50 percent (p. 10, TOV-Rheinland; P. 33, Transport Canada), and to reduce seat bench usage from three to two passengers so belts can be placed at uniform intervals wide enough to accommodate passengers of all sizes (p. 15, NHTSA, 1985; p. 4-7, CHP, 1987). As a consequence, a "full size" bus could contain only 10 rows of four students each (40 passengers)—instead of 14 rows of six students each (84 passengers). These two parameters alone will reduce the capacity of school buses **to less than half their present capacity!** Nationwide, this capacity reduction would translate into the need to **more than double** the size of the existing fleet from 400,000 to more than 800,000 vehicles--an economic undertaking which could require tens of billions of dollars. Quite simply, such an undertaking is a financial impossibility—not to mention better uses of such funds, were they indeed available.

- Two major studies of seat belt usage in school buses found that, without strong monitoring and enforcement, only a small percentage of the students used their belts (pp. 9, 13, 61, 74, 92, CHP/SRI, 1977). Other studies have contradicted these experiences: Two New York school districts claimed usage rates of 80 percent with or without monitors (p. 13, NHTSA, 1985). And a more recent study in New York State ("1998 Seat Belt Usage Survey" by the Pupil Transportation Safety Institute for the State Education Department of New York) found significantly higher rates of usage—although compliance varied considerably with age: Reported compliance was 88 percent for elementary school-, 71 percent for middle school-, and 47 percent for high school students. Regardless of the exact percentage—which will likely vary from district to district and from bus to bus—***ensuring*** usage means that a second adult would have to ride the bus along with the driver--effectively doubling the size of the work force operating the vehicles. It is also difficult to determine what experiences regarding seatbelt ***usage*** really mean in terms of school bus ***safety***: A March, 1990 report from the New York Association of Pupil Transportation claimed that "…seat belt-related injuries **increased 460 percent** since last year's survey" (p. 84, CUTR, 1993)**.**

  This illustration points out an important and often-overlooked advantage of compartmentalization: **The *passenger* does not have to do anything to make it work.** This important benefit of ***passive*** restraint systems (compared to ***active*** restraint systems, like seat belts) has enormous merit. With active systems, passengers must not only engage them, but engage them properly. With passive systems like compartmentalization, passengers need only remain seated for the system to work optimally.

- Seat belts must be accompanied by provisions for uniform usage among all students. Given the plethora of other design changes needed to optimally accommodate seat belt technology (including changes to the seat and seat structure), one's failure to use his or her belt would expose the passenger (and fellow passengers) to far greater risks than exist with the current approach (i.e., compartmentalization). This is particularly true as the secondary rebounds demonstrated in all the crash-test studies (UCLA, Transport Canada, CHP/SRI) were the most bizarre, unpredictable and severe when a mix of belted and unbelted passengers were involved. So, in addition to the monitoring and enforcement activities such a policy may necessitate, special training and motivation may also need to be provided to all students.

- Occurrences of seat belt and retractor misuse, abuse, vandalism, maintenance, repair, theft and replacement could create institutional problems as well as maintenance and insurance issues (p. 14, CHP/SRI, 1977; pp. 82-84, CUTR, 1993). For example, what percentage of non-functioning seat belts would be acceptable? Should this percentage be uniform throughout the United States? Should schools with more student behavior problems have lower standards?

- Seat belts might translate not only into the need for increased liability insurance at the operating level, but increased product liability insurance at the manufacturing level (p. 32, CHP/SRI, 1977; p. 4-7, CHP, 1987)--costs for which would likely translate into fewer schoolbuses available.

- Including seat belts on school buses would have "carryover effects" in other applications. For example (and contrary to arguments often offered in favor of seatbelts on school buses), a child's failure or refusal to use seat belts on a school bus could undermine his or her practice of using them in automobiles--**where seats are not compartmentalized, rollovers and ejection far more common, and seat belts indisputably of great value**. As an illustration of the degree to which this is the case, the regular use of seatbelts on school buses has not proven to "carry over" to usage **even on other buses equipped with seatbelts** (Gardner et. al, 1986. School Bus Safety Belts: Their Use, Carryover Effects and Administrative Issues. Office of Driver and Pedestrian Research, National Highway Traffic Safety Administration, Washington, D.C.).

- The manufacture and installation of seat belts would generate a wide range of indirect costs including those associated with tooling, maintenance, monitoring, enforcement and discipline (for failure to properly use the belts), as well as "hidden" manufacturing costs such as modifications to bus floors, seat anchorages, seat belt anchorages and other structural changes which would be needed to accommodate the seat belt systems. For example, plywood floors would have to be reinforced with metal plates or oversized "washers" (buses manufactured since the early 1990's don't have such floors). And diagonal frame members may be needed to support the loads on the floor (from a bus full of belted passengers) to prevent the floor from buckling. Given the need for these structural modifications, it would cost **significantly** more to retrofit seat belt systems to an existing bus than to install them properly in a new one (pp. 30-40, CHP/SRI, 1977).

- The added weight from the belts, retractors and structural changes would increase overall vehicle weight and trigger a number of multiplier effects such as reduced fuel efficiency, more brake and tire wear, and the need for more horsepower and torque in the engine and transmission (which would in turn add still more weight to the bus). Of course, the reduction in seating capacity which this added weight would bring about on large buses (in order to comply with axle weight limits) would be academic if one respected the need to dramatically reduce seating capacity anyway in response to increased seat-spacing requirements and the need to decrease seat positions per bench from three to two (to accommodate uniform seat belt positioning).

- The issue of whether seat belts should be retrofitted into existing buses, and the determination of how old a bus should be retrofitted, lies apart from the issue of incorporating this technology into new buses (pp. 29-31, CHP/SRI, 1977). At what point in a schoolbus's life cycle is such a retrofit no longer economically infeasible? Should "spares" be retrofitted? Would the rights of students riding in these vehicles be violated (even though the studies cited in this analysis suggest strongly that they would be safer without seatbelts)? Perhaps for such reasons, all seven school bus manufacturers (in 1983)**--as well as the National Coalition for Seat Belts on School Buses--**advised NHSTA against retrofitting lap belts to existing school buses (p. 10, NHTSA, 1985).

While the pupil transportation community may not have assembled the litany of factors cited above into a single document, many and various members of this community are aware of, and sensitive to, a great many of them. Accordingly, many of these points have been articulated by a wide range of interested and informed parties and individuals—apart from their appearance in three decades of studies, crash tests and accident investigations and analyses. So it should be no surprise that every North American organization (with the exception of two state legislatures) responsible for the regulation of school bus safety and/or involved in the development of recommendations for improving it is either opposed to the use of seat belts in school buses or feels that they are not needed. In the United States, these institutions include the National Highway Traffic Safety Administration, National Transportation Safety Board, National Association of State Directors of Pupil Transportation Services, National Association of Pupil Transportation, National School Transportation Association, National Standards Conference, and National Academy of Sciences. Even the National Safety Council--a major and vocal proponent of seat belt usage in passenger automobiles--objected to the use of documents "out-of-context" cited by the media as evidence of its support for seat belts on school buses.

In contrast, the organizations which favor the installation of seat belts on school buses are largely single-issue advocacy groups comprised of parents, physicians or other individuals outside the transportation field who generally do not acknowledge or discuss many (or most) of the considerations presented above. To be fair, few members of the pupil transportation community are familiar with the enormous number of reasons for not installing this technology. So one can hardly expect non-transportation professionals to be familiar with them. Unfortunately, past decisions to include seat belts in school buses were not made by individuals with this knowledge or these arguments at their disposal.

CONCLUSIONS

One of the strongest arguments for the exclusion of seat belts from school buses is simply that they are not needed. For the reasons outlined above and many others, U.S.-manufactured school buses have an outstanding safety record and experience extremely low fatality rates **in all accident scenarios**, notwithstanding rare catastrophic accidents where common sense suggests seat belts would have **increased** the casualty rate either by further impeding vehicle evacuation (Carrollton, Alton), or by cutting passengers in half or launching them, with their seat modules, into sidewalls or other objects in the bus (Palms Springs, Fox River Grove). Results of the UCLA and Transport Canada crash-testing programs virtually predict the likelihood of such results. The lives lost in this way from a single catastrophic accident could offset the limited number of lives (if any) that seat belts might otherwise save in those rare accidents, like rollovers, where passengers could be ejected or tossed about within the passenger compartment. And these vehicles already contain an approach to occupant protection--compartmentalization--which has repeatedly proven to work effectively (p. 317, UCLA, 1967; pp. 2-4, CHP/SRI, 1977; p. 76, Transport Canada, 1984; pp. 2-4 and 3-8, CHP, 1987; p. 9, NHTSA, 1985).

With the current height of seat backs (in most states and school districts) and spacing between seat rows, seat belts will cause more injuries than they will prevent. While seat belts will occasionally prevent ejections and minimize passenger impacts with interior vehicle elements, these occurrences are rare in even most severe accidents. Further, the number and severity of accidents will increase with the inclusion of seat belts unless vehicle capacity is reduced by more than 50 percent to accommodate this technology.

Given the absence of benefits from the installation of seat belt technology, it is obvious there are far better uses of the funds needed to do so properly, uses which would contribute greatly to genuine improvements in school bus safety (pp. 15, 16, NHTSA, 1985); p. xi, CUTR, 1993). These alternate improvements range from increased seat back heights, improved driver training and education, improved passenger monitoring systems and improved bus sidewall padding (as per Final Rule, August 18, 1995, Federal Register) to the expansion **or restoration** of school bus service itself to millions of schoolchildren without it.

Most importantly, the numerous problems with the installation and use of seat belts compound one another. Variables in seats and seat belt systems are further compounded by variations among the passengers carried, the range of other vehicle types involved in collisions with school buses, accident modes, and the sequential rebounding of movement within the passenger compartment following the initial impact force. When all these factors are considered, it is clear that no seat belt system works optimally for all passengers in all accident scenarios. Given the compartmentalization already integrated into these vehicles, school bus **passengers are far safer without seat belt technology** (pp. 54, 82, CHP/SRI, 1977; pp. 49, 76, Transport Canada, 1984; p. 3-8, CHP, 1987).

There are indeed a considerable number of discrepancies among the many studies examined in the preparation of this analysis. Many of these stem from the fact that the various testing programs involved different buses during a 27-year period. Many studies also acknowledged dissenting opinions. Many conclusions, as well as study methodologies, have been strongly criticized. And certain deficiencies identified in various studies have been addressed (primarily by NHTSA) as school bus safety evolved over the years during which these studies were conducted. Finally, this analysis suffers from the lack of information from similar studies conducted on other continents on very different types of buses and coaches, with the exception of the inclusion of the FRG/TÖV Rheinland study, which corroborates many conclusions of key U.S. and Canadian studies.

Despite the difficulties of the subject matter, further study could be of enormous value--particularly given the importance of the issue, the number of pro-seat belt advocates, and the clarity and validity that study results would provide in support of, or against, their positions. At the same time, further study is likely to reveal new issues—as, for example, problems which could emerge in making the litany of structural and other technical changes that may be required to accommodate the installation of seat belt technology.

Regardless of the outcome, it is clear that no approach to school bus safety technology is without its tradeoffs. For every accident scenario in which a certain technology may provide benefits to certain passengers, there will likely be other accident scenarios—and other passengers involved in even the same scenarios—who will be adversely affected by it. Serious and fair-minded decision makers armed with the results of further studies will have the unenviable task of making these tradeoffs. It should be clear from the analysis above that no trade-off will or can possibly please everyone, just as it will not **help** everyone. The issue of seat belt installation will likely remain a controversy regardless of how it is "resolved." The hope is that the tradeoffs made will save more lives than they will sacrifice, and will prevent more fatalities, and minimize the severity of more injuries, than they will cause.

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