Safety Belt
Countermeasures Study
Final Report

U.S. Department of Transportation
Federal Motor Carrier Safety Administration

December 2007

FOREWORD

This report addresses two different but interrelated topics of research. The first topic is the review of existing and potential future technologies that could improve safety belt use rates by drivers of large trucks (gross vehicle weight rating [GVWR] of 10,001 pounds or more). The second presents an analysis of real-world crash data, identifying common characteristics of fatal and serious injury crashes involving Commercial Motor Vehicle (CMV) drivers. The analysis explores the potential impact of increased safety belt use on driver fatalities and serious injuries. The Fatality Analysis Reporting System (FARS) and the Large Truck Crash Causation Study (LTCCS) databases were used to perform the review.

This report discusses currently available technologies identified during a systematic review of technical publications and other available information sources. A summary of industry stakeholder and CMV driver perspectives regarding each technology is provided. Stakeholders included members of the CMV Safety Belt Partnership such as vehicle and restraint manufacturers, insurance, government, and CMV drivers. The results of an estimated benefit-cost analysis are provided to compare potential injury and fatality reductions with estimated device costs.

The data analysis tasks identified key environmental, vehicle, and driver factors describing the belted and unbelted driver populations. Causes of rollover crashes are identified and the impact of safety belt use on injury and fatality outcomes are explored.

NOTICE

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Mr. Jerry Robin was the Contracting Officer's Technical Representative (COTR) for this project.

16. Abstract:

Safety belts are the single most effective injury prevention component of highway vehicles today. In 2006, observational studies reported that safety belt use by drivers of Class 7 and 8 trucks was 59 percent compared with an 81 percent belt use rate for passenger vehicle drivers. This study explored addresses two topics of research. The first topic explored technologies designed to increase safety belt use by commercial motor vehicle (CMV) drivers. Four promising technologies likely to increase safety belt use were identified: (1) Enhanced Audible Reminder Systems, (2) Brightly Colored Safety Belts, (3) Safety Belt Tension Adjustors, and (4) Seat-Integrated Safety Restraint Systems. A cost-benefit analysis was performed, indicating that brightly colored safety belts and enhanced audible reminders are both cost-beneficial solutions, suggesting that the likely injury cost savings due to increased safety belt use will exceed the cost required to equip one vehicle with the device. At the present time, no Federal regulations exist that require safety belt reminder systems of any kind (audible or visual) for CMVs. Conversely, for passenger vehicles, the Code of Federal Regulations Part 571, Federal Motor Vehicle Safety Standard Number 208, requires that audible and visual reminder systems are installed at the driver's seating position. This requirement has been in place since 1974.

The second topic of research employed the FARS, NASS, GES, and LTCCS databases to perform a detailed analysis of fatal and serious injury crashes and to identify characteristics of the unbelted driver population. The analysis also explored the causes of rollover crashes and the likely impact of belt use on the frequency of driver injuries and fatalities. The data analysis identified that for both belted and unbelted drivers, the majority of CMV driver fatalities occurred during rollover crashes, followed by impacts with other vehicles. A review of unbelted driver fatalities and serious injuries indicated that 39 percent of unbelted driver fatalities (138 drivers per year) could be prevented with safety belt use and 47 to 81 percent of moderately to seriously injured drivers (1,600 to 2,500 drivers per year) could have sustained injuries less severe if they were properly restrained

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SI* (MODERN METRIC) CONVERSION FACTORS

APPROXIMATE CONVERSIONS TO SI UNITS					APPROXIMATE CONVERSIONS FROM SI UNITS				
Symbol	When You Know	Multiply By	To Find	Symbol	Symbol	When You Know	Multiply By	To Find	Symbol
		LENGTH					LENGTH		
in	inches	25.4	millimeters	mm	mm	millimeters	0.039	inches	in
ft	feet	0.305	meters	m	m	meters	3.28	feet	ft
yd	yards	0.914	meters	m	m	meters	1.09	yards	yd
mi	miles	1.61	kilometers	km	km	kilometers	0.621	miles	mi
		AREA					AREA		
in^2	square inches	645.2	square millimeters	mm^2	mm^2	square millimeters	0.0016	square inches	in^2
ft^2	square feet	0.093	square meters	m^2	m^2	square meters	10.764	square feet	ft^2
yd^2	square yards	0.836	square meters	m^2	m^2	square meters	1.195	square yards	yd^2
ac	acres	0.405	hectares	ha	ha	hectares	2.47	acres	ac
mi^2	square miles	2.59	square kilometers	km^2	km^2	square kilometers	0.386	square miles	mi^2
		VOLUME					VOLUME		
fl oz	fluid ounces	29.57	milliliters	ml	ml	milliliters	0.034	fluid ounces	fl oz
gal	gallons	3.785	liters	l	l	liters	0.264	gallons	gal
ft^3	cubic feet	0.028	cubic meters	m^3	m^3	cubic meters	35.71	cubic feet	ft^3
yd^3	cubic yards	0.765	cubic meters	m^3	m^3	cubic meters	1.307	cubic yards	yd^3
		MASS					MASS		
oz	ounces	28.35	grams	g	g	grams	0.035	ounces	oz
lb	pounds	0.454	kilograms	kg	kg	kilograms	2.202	pounds	lb
T	short tons (2,000 pounds)	0.907	megagrams	Mg	Mg	megagrams	1.103	short tons (2,000 pounds)	T
		TEMPERATURE (exact)					TEMPERATURE (exact)		
°F	Fahrenheit temperature	5(F-32)/9 or (F-32)/1.8	Celsius temperature	°C	°C	Celsius temperature	1.8 C + 32	Fahrenheit temperature	°F
		ILLUMINATION					ILLUMINATION		
fc	foot-candles	10.76	lux	lx	lx	lux	0.0929	foot-candles	fc
fl	foot-lamberts	3.426	candela/m2	cd/m2	cd/m2	candela/m2	0.2919	foot-lamberts	fl
		FORCE and PRESSURE or STRESS					FORCE and PRESSURE or STRESS		
lbf	pound-force	4.45	newtons	N	N	newtons	0.225	pound-force	lbf
psi	pound-force per square inch	6.89	kilopascals	kPa	kPa	kilopascals	0.145	pound-force per square inch	psi

*** SI is the symbol for the International System of Units. Appropriate rounding should be done to comply with Section 4 of ASTM E380.**

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ACRONYMS

ABS	Antilock Brake (or Braking) System
ADR	Australian Design Rule
AIS	Abbreviated Injury Score
ATRI	American Transportation Research Institute
BCA	Benefit-Cost Analysis
BCR	Benefit-Cost Ratio
BMI	Body Mass Index
CDS	Crashworthiness Data System
CHAMPUS	Civilian Health and Medical Program of the Uniformed Services
CMV	Commercial Motor Vehicle
DCI	Detailed Claims Information
DOT	Department of Transportation
EOBDR	Electronic Onboard Data Recorder
FARS	Fatality Analysis Reporting System
FHWA	Federal Highway Administration
FMCSA	Federal Motor Carrier Safety Administration
FMVSS	Federal Motor Vehicle Safety Standards
GES	General Estimates System
GVWR	Gross Vehicle Weight Rating
HARM	Hazard Assessment Rating Methodology—a metric used to characterize the number and severity of injuries sustained and overall cost to society
LTCCS	Large Truck Crash Causation Study
MAIS	Maximum Abbreviated Injury Score
MVOSS	Motor Vehicle Occupant Safety Survey
NASS	National Accident Sampling System
NCCI	National Council on Compensation Insurance
NHTSA	National Highway Traffic Safety Administration
NMES	National Medical Expenditure Survey
NOPUS	National Occupant Protection Use Survey
NTC	National Transport Commission
NTSD	National Truck Driving Championships
OEM	Original Equipment Manufacturer
SOII	Survey of Occupational Injury and Illness
TMA	Truck Manufacturers Association

EXECUTIVE SUMMARY

The first goal of this project was to identify promising technologies to increase safety belt usage by commercial motor vehicle (CMV) drivers. Each technology could be classified in one of three categories: (1) Comfort Strategies, (2) Reminder Strategies, or (3) Enforcement Strategies. The second phase of the study involved the analysis of real-world crash data from the Fatality Analysis Reporting System (FARS), National Accident Sampling System (NASS), and General Estimates System (GES) databases and the Large Truck Crash Causation Study (LTCCS) database to identify characteristics of fatal and serious injury crashes involving CMV drivers. The analysis considered common characteristics of belted and non-belted drivers of all large trucks, defined as any vehicle with a Gross Vehicle Weight Rating (GVWR) over 10,000 pounds.

This study identified four promising technologies likely to increase safety belt use. These are: (1) Enhanced Audible Reminder Systems, (2) Brightly Colored Safety Belts, (3) Safety Belt Tension Adjustors, and (4) Seat-Integrated Safety Restraint Systems. These technologies provide audible and visual reminders for drivers to buckle up or they improve the comfort of existing safety belt systems to address complaints made by some drivers.

During the study, technologies to increase safety belt usage were identified during a systematic review of technical publications and other available information sources. This report contains a brief description of each technology considered. Discussions with industry stakeholders, including vehicle and restraint manufacturers, trade organization representatives, insurance and safety researchers, and CMV drivers, were conducted to better understand their perspectives on the safety belt use problem and the various technologies considered. A benefit-cost analysis was performed to estimate the potential injury and fatality cost savings likely if a fleet owner or vehicle owners chose to equip their vehicles with any of the devices in question.

The study concluded that increased safety belt usage would reduce the number of seriously and fatally injured drivers. The economic burden associated with these casualties due to non-use of safety belts for drivers of large trucks is estimated to be $675 million annually. The cost of unbelted driver injury and fatality is $490 million for Class 7 and 8 trucks. In general, only approximate estimates of the effectiveness of each device in increasing safety belt use can be made because many of these systems have not been formally evaluated. However, study results indicate that if a device increases safety belt use by at least 15 percent, e.g., increases the rate from 59 percent to 74 percent, and the device cost is $273 or less per vehicle, the device is considered to be cost beneficial. For Class 7 and 8 trucks alone, if the device costs less than $725 and is 15 percent effective in increasing safety belt wearing rates, the system is cost beneficial. Most of the technologies considered during this study are significantly less expensive than $725 and would therefore be cost-beneficial solutions to increase safety belt use. If a device increases safety belt use by as little as 5 percent, then a device that costs as much as $91 for all large trucks or $240 for Class 7 and 8 trucks would be cost beneficial.

Based on estimates performed here, brightly colored safety belts and enhanced audible reminders are both assumed to be cost-beneficial solutions. Their anticipated benefit cost ratios (BCRs) are 1.70 and 2.60, respectively, for all large trucks. If the benefit cost ratio is greater than 1 for a particular device, it can be considered to be a cost-beneficial solution where the predicted injury

cost savings due to increased safety belt usage exceeds the cost required to equip one or more vehicles with the device. For drivers of Class 7 and 8 trucks alone, brightly colored safety belts and enhanced audible reminders have BCRs of 4.5 and 6.9. Alternatively, seat-integrated safety restraints could offer an enhanced comfort solution, yet device costs exceed the likely benefit of the proposed system based on calculations performed here. Safety belt tension adjustors (Komfort Latch), which are widely available today, are well suited to help CMV drivers configure safety belt systems for optimal comfort; however, significant driver education and training must occur in order to realize maximum effectiveness in increasing safety belt usage for these devices.

The data analysis tasks (of the various DOT data crash systems, including GES, LTCCS, FARS) performed here identified key factors of the belted and unbelted CMV driver population. For both belted and unbelted drivers, the majority of CMV driver fatalities occurred during rollover crashes followed by impacts with other vehicles. A review of belted-driver fatalities indicated that virtually all rollovers involved significant damage to the occupant compartment. The most common crash types where a belted driver dies were rollovers with considerable roof crush or during events with side compartment intrusion. Further, impacts with fixed objects including roadside objects like bridge abutments and trees occur frequently during fatal crashes. Upon review of unbelted-driver fatalities and serious injuries, it was estimated that 39 percent of fatalities (138 drivers per year) could be prevented with safety belt use and 47–71 percent of moderately to seriously injured drivers (1,600–2,500 drivers per year) could have sustained injuries less severe if they were all properly restrained.

Overall, increased safety belt use by drivers of large trucks would reduce the frequency and severity of driver injuries and fatalities. Several promising technological approaches likely to increase safety belt usage have been identified by this study. Some approaches must be adopted voluntarily by vehicle manufacturers or fleet owners when purchasing vehicles. Others could be addressed through improvements in existing regulations. The required introduction of basic audible or visual reminder systems would have some positive effects; however, the implementation of an enhanced system would likely bring a greater positive change in safety belt use.

1. INTRODUCTION

Safety belts are the single most effective injury prevention component of highway vehicles today. In the event of a crash, they are designed to prevent occupant ejection, limit excursion to prevent harmful contact with interior components, and minimize forces experienced by occupants as they are decelerated from driving speeds to rest. These primary functions of safety belts are true for any vehicle type. In all but one state, the use of safety belts is required for any person occupying a front-seat position in any motor vehicle, including large trucks. However, recent observational studies conducted in 2006 have shown that safety belt use by drivers of Class 7 and 8 trucks was only 59 percent overall. The most recent National Occupant Protection Use Survey (NOPUS), conducted in 2006, revealed that shoulder safety belt usage was 81 percent for passenger vehicle drivers.

This study investigates potential ways to increase safety belt usage for drivers of all large trucks with a Gross Vehicle Weight Rating (GVWR) of 10,001 pounds or more. For the remainder of this report, these vehicles are referred to as “All Large Trucks,” and in some cases they are referred to as Commercial Motor Vehicles (CMVs) as well.

Many challenges are presented when attempting to lower safety belt use rates for drivers of large trucks. First, enforcement of safety belt use laws is more difficult for these drivers. Higher ride heights and enclosed occupant compartments obscure drivers from the view of police and U.S. Department of Transportation (DOT) inspection personnel. Multiple studies have shown that enactment and enforcement of safety belt use laws are the best way to improve safety-belt-wearing rates for passenger vehicle drivers, yet drivers of large trucks do not appear to be as affected by these laws, due to the reduced threat of being identified as unbelted while driving and then ticketed. Also, given the size of the tractor trailers and their mass, these drivers feel safe not being buckled up.

Drivers of CMVs have also indicated that safety belts are uncomfortable to wear while driving, and cite this as a primary factor in their decision not to buckle up. Although no scientific data support the claim that safety belts are uncomfortable in large trucks, varied seating geometry, suspended seating systems, and harsh rides, which are common in large trucks, could be responsible for the perceived discomfort.

The goal of this study was to identify and evaluate promising technologies that could increase safety belt usage by CMV drivers. The study began with a review of all available scientific literature describing previously implemented technologies, currently available systems, and device concepts not already in use. Literature sources were selected that describe technologies specifically designed for large truck applications and those describing passenger vehicle systems that could be applied in large trucks.

Discussions with trucking industry stakeholders were conducted to determine their perspectives on the CMV driver safety belt use problem and to seek their feedback regarding each potential device identified. Key findings of stakeholder discussions are presented in Chapter 4. Stakeholders included vehicle original equipment manufacturers (OEMs) and restraint manufacturers, trade organization representatives, fleet safety managers, government personnel and trade association representatives, as well as insurance representatives; the vast majority of these stakeholders are members of FMCSA's CMV Safety Belt Partnership. Chapter 4 also presents perspectives of CMV drivers regarding the various technologies considered. Discussions were held with full-time and part-time safety belt users and nonusers of safety belts. Based on industry stakeholder and driver feedback and through confirmation by drivers, the study focused on four promising technologies. These promising systems include: (1) Enhanced Audible Reminder Systems, (2) Brightly Colored Safety Belts, (3) Safety Belt Tension Adjustors, and (4) Seat-Integrated Safety Restraints.

A benefit-cost analysis (BCA) was conducted to determine the monetary impact of increased safety belt use by drivers of all large trucks and by drivers of Class 7 and 8 trucks. This analysis is presented in Chapter 5. Results are presented in two generalized tables where benefit-cost ratios (BCRs) are calculated across a range of plausible device costs and a range of possible effectiveness values. This approach allows for the application of study results to estimate an approximate return on investment expected for any device that leads to an increase in safety belt use, as long as its cost and anticipated effectiveness are known.

Within Chapter 6, a synthesis of information describing each of the four promising technologies is presented. This information includes any data discovered during the review of scientific literature and obtained from the stakeholders. A benefit-cost calculation tailored for each device is performed. In addition, a discussion of the implementation strategy and potential shortcomings of each system is provided.

Chapter 7 presents the results of a general analysis of large-truck crash data. Within section 7.1, the 2005 Fatality Analysis Reporting System (FARS) data were reviewed to contrast vehicle, environmental, and personal characteristics for unbelted versus belted drivers of large trucks. The analysis was conducted to characterize the unbelted fatally injured population so that strategies can be generated to reduce the magnitude of this population.

Chapter 7 also provides a detailed analysis of belted-driver fatal and serious-injury crashes, based on LTCCS data. This review was designed to better understand what factors led to fatalities for occupants who were properly restrained. The analysis also describes crash conditions not affected by safety belt usage.

In addition, Chapter 7 presents a second evaluation using the LTCCS data to better understand primary causes of large-truck rollover crashes. Detailed crash case reviews were conducted to determine principal and secondary factors associated with rollovers. Factors were compiled based on crash-investigator-recorded data, as well as non-coded information collected during detailed clinical case reviews. Results of a subsequent factor analysis are presented, highlighting the most common contributors to the initiation of rollover crashes for all large trucks.

2. LITERATURE REVIEW

A focused literature review was conducted to better understand technologies, including those in passenger cars, that are likely to increase safety belt usage by drivers of CMVs/all large trucks. In addition, the review sought to understand experiences of others who had systems implemented in the past. All available CMV safety belt technology studies and relevant passenger vehicle studies are presented. Literature search findings are grouped by their primary subject matter and placed in one of three topic categories, including comfort, reminder devices, and general information.

2.1. COMFORT

Four technical publications were found relating to safety belt comfort. These studies were based both on large truck applications and passenger vehicles.

The first study, published by the National Transport Commission (NTC) of Australia (2004), investigated the hypothesis that safety belt comfort issues needed to be resolved in order to contribute to better wearing rates. The report, titled “Seat and Belt Configurations for Heavy Vehicles: Discussion Paper on Options for Improved Design,” considered 2004 new heavy vehicles sold in Australia in 2004 from the Truck Industry Council’s truck tracker data. Objectives of the study were to review the availability of seat and safety belt configurations in commercial vehicles sold in Australia and to test the theory that nonuse of CMV safety belts is due to discomfort. In particular, the study explored the current market presence, feasibility, and availability of seat-integrated safety restraints.

Overall, the NTC of Australia study concluded that a compulsory standard requiring certain seat and safety belt configurations could lead to increased numbers of more comfortable safety belt systems. The authors suggested the following: (1) suspended seats with B-pillar mounted restraint systems provide reduced comfort to occupants due to the relative motion of the seated driver and belts that lead to excessive rubbing; (2) a fixed seat with a fixed safety belt system offers adequate comfort and is comparable to the same configuration in a passenger vehicle; and (3) a suspended seat with an integrated safety belt offers improved comfort.

The NTC of Australia study identified that 46 percent of new heavy vehicles sold in Australia have fixed seats and B-pillar anchored safety belts, 31 percent have suspension seats and B-pillar anchored safety belts, and 23 percent have suspension seats and seat-integrated safety belts. The 31 percent of vehicles sold with suspension seats and B-pillar anchored safety belts present an opportunity to improve the comfort of safety belts for new vehicles or retrofitted vehicles in the fleet.

The NTC authors also identified that 12 percent of the fleets sold in Australia did not have cab designs with sufficient strength to withstand loads from a seat-integrated safety belt system. The authors suggested that European manufacturers are delivering 98 percent of new vehicles with safety belt configurations that are more comfortable than the B-pillar mounted system with a suspended seat. These included fixed seats with B-pillar mounted safety belts and suspended seats with seat-integrated safety restraints. The authors suggested that American manufacturers are seeing increased demand for seat-integrated safety restraints, although 20 percent of new vehicle deliveries in 2004 were suspended seats with B-pillar mounted safety belt systems.

The NTC study also compared reasons for resistance or nonuse of safety belts by truck drivers today and identified reasons given by passenger vehicle drivers for nonuse of safety belts when they were first introduced in those vehicles. Reasons cited by drivers were reported by Preece (2002) and include the following:

- Restriction in the use of side mirrors
- Discomfort during normal driving
- Inconvenience when performing deliveries
- Impeding the driver's ability to move within or escape from the cabin in order to avoid injury during or after a collision
- Difficulty in accessing and unlocking the safety belt
- Getting entangled in the safety belt when exiting the cab

Educational campaigns and high levels of enforcement were suggested to address these concerns.

A study by Bergoffen, et al. (2005) summarized key information regarding factors that influence CMV drivers to use or to not use safety belts. The research was supported by DOT, Federal Motor Carriers Safety Administration (FMCSA). The study report included a literature review summarizing past and ongoing research on safety belt use by CMV drivers. A second source of information described in the report came from surveys of fleet managers and drivers.

Bergoffen conducted truck stop interviews with 238 CMV drivers in Georgia and Wisconsin using a convenience sample. Commercial motor vehicle drivers were administered a five-minute interview where drivers were asked what percentage of the time they wore their safety belts while driving a truck. Of those interviewed, 61 percent reported wearing safety belts 95 percent or more of the time, and 21 percent of drivers reported wearing safety belts 5 percent or less of the time. Compared to the automobile driving population, where the group of habitual nonusers is 4 percent, this group of CMV drivers has more habitual nonusers, at 21 percent. There are also fewer full-time safety belt users among this group than in the general driving population—61 percent compared to 76 percent, at the time the survey was conducted. The CMV drivers reported similar safety-belt-use behavior when driving their personal vehicles; that is, those that were not belted in trucks were also not belted in their cars.

In Bergoffen's study, the top reasons provided by the CMV drivers for not wearing a safety belt were: (1) comfort, (2) personal choice, and (3) dislike of wearing a safety belt. In the truck stop survey, drivers were asked about their biggest complaint regarding safety belts. Approximately 62 percent responded to this question and of these, 28 percent (148) said they had no complaints about safety belts. The majority of the complaints referred to comfort issues, with only a few complaints about enforcement and personal choice. The major complaints about safety belt comfort were safety belt rubbing or vibrating against neck/shoulder, locking of safety belts, safety belt being uncomfortable, safety belt being too tight, and safety belt having a limited range of motion. The major suggestions that drivers gave to make the safety belt easy to use were that it should: not be too tight, not interfere with driving, be easy to put on and take off, and be easy to position.

In a survey of 120 fleet managers, Bergoffen stated that the managers provided the following reasons that drivers might not use safety belts: too much trouble and effort, just forgot, not a habit, belt does not fit well, uncomfortable for other reasons, restricts movement in vehicle, infringes on personal freedom, worries about being trapped in vehicle, don’t believe belts increase safety, just don’t like them, part-time users, and used only in bad weather.

Two focus groups were held with CMV drivers during the Bergoffen study in Utah; one with seven drivers at the National Truck Driving Championships (NTDC) and one with four drivers at a private trucking terminal dubbed “Company A.” These focus groups were small and were held with groups of drivers who would be expect better safety related behaviors than the general CMV-driving public. Drivers from the Company A group indicated that because of the company’s strong belt policy, they all wore safety belts 100 percent of the time. The NTDC drivers did not wear belts all of the time. One stated that it was because it was not convenient when delivering door-to-door. Participants felt that of the valid reasons for not wearing a safety belt, discomfort was a top choice.

During the evaluation, Bergoffen’s research team also conducted an ergonomics assessment of existing truck safety belts. The evaluation concluded that safety belts in large trucks are practical and functional. Researchers identified that safety belt systems are suitable for the majority of the population (20th percentile through the 80th percentile); however, safety belts do not serve well the population of large, heavy-set, obese drivers or the population of drivers of small stature. The study identified two features in new safety belts that make the placement of the shoulder strap more flexible. These are the adjustable height D-ring and the shoulder strap tension adjuster. The study also suggested that seat-integrated safety belts may enter the U.S. market; however, structural requirements, including crash test requirements, must first be addressed by manufacturers.

In 2003, DOT established the CMV Safety Belt Partnership in response to the “Safety Belt Usage by Commercial Motor Vehicle (CMV) Drivers” study, which found that only 48 percent of CMV drivers were wearing their safety belts, compared to 80 percent of passenger vehicle drivers. The partnership is dedicated to increasing safety belt use among CMV drivers. In 2006, a similar CMV driver safety belt observation study was conducted by the National Highway Traffic Safety Administration (NHTSA) for FMCSA that showed usage had increased to 59 percent, compared to 81 percent for passenger vehicle drivers.

The CMV Safety Belt Partnership is comprised of the following organizations:

- American Trucking Associations (ATA)
- American Association of Motor Vehicle Administrators
- American Society of Safety Engineers (ASSE)
- Commercial Vehicle Safety Alliance (CVSA)
- Federal Motor Carrier Safety Administration (FMCSA)
- Great West Casualty Company

- International Association of Chiefs of Police (IACP)
- National Association of Truck Stop Operators (NATSO)
- National Association of Publicly Funded Truck Driving Schools
- National Highway Traffic Safety Administration (NHTSA)
- National Private Truck Council (NPTC)
- National Safety Council
- National Tank Truck Carriers
- Network of Employers for Traffic Safety
- Owner-Operator Independent Drivers Association (OOIDA)
- Truck Manufacturers Association
- Property Casualty Insurers Association of America
- Truckload Carriers Association, Professional Truck Drivers Institute

For more information about the partnership, visit *www.fmcsa.dot.gov/safetybelt*.

Hayworth, et al. published “Truck Seat Belts” in 1996. The goals of the study were to determine the following: how many and what groups of heavy vehicle drivers did not wear safety belts; why truck drivers did not wear safety belts; what effect, if any, the changed Australian Design Rule (ADR) had had on wearing rates and whether further safety belt design improvements were required; what was necessary to achieve greater wearing rates; and the guidelines for the development and conduct of a communications strategy to improve safety belt wearing.

According to Hayworth’s study, the ADR was changed (effective July 1992) so that safety belts could be anchored to vehicle seats and so that retractors (web-lockers) could be made less sensitive. The extent to which these changes (which made truck safety belts more comfortable) increased safety belt usage was explored. Findings indicated that wearing rates were higher in new trucks than in older trucks. This suggests that the changed ADR has improved wearing rates. However, when wearing rates were analyzed, drivers with seat-mounted safety belts were no more likely to wear the safety belt than those with vehicle-mounted systems.

Balci, Vertiz, and Shen (2001) published a study that considered the comfort and usability of safety belts in passenger vehicles. During the study, 600 questionnaires were distributed and 192 (32 percent) were returned. There was no information provided on who received the questionnaires. The low response rate and the skewed demographics (69 percent male, over 50 percent between 41–55 years old) indicated that this population is not representative of the general passenger-vehicle-driving population.

Balci, Vertiz, and Shen also conducted a survey to collect first-hand information regarding safety belt comfort and usability. The most significant problems with safety belts were: safety belt trapping in the door, awkward negotiating with clothes, safety belt twisting, safety belt locking up, and difficulty locating the buckle. The survey results indicated that drivers who are over 40 years old had more complaints than younger drivers. When the driver’s age increased to 55 or more, safety belt pulling force and inappropriate and loose fit of the safety belt on the body became major issues. Female drivers had more complaints than male drivers. Drivers of short stature need both hands to pull and guide the safety belt. The participants who were in the 66th percentile or higher in terms of weight had complaints about safety belt twisting. Coupe-type vehicles had the least comfortable safety belts compared to other vehicle types. The most comfortable safety belts were found in sedan and SUV-type vehicles.

2.2. REMINDER DEVICES (PASSENGER VEHICLES)

In a 2002 study, Fildes, et al. estimated the “Benefits of Seat Belt Reminder Systems” for the Australian population. The study presented results of an analysis of an aggressive safety belt reminder system for passenger vehicles to determine how cost-beneficial each of the systems would be for Australia. The three systems analyzed were: (1) a simple flashing light and warning tone, (2) a simple flashing light and warning tone where intensity increases with higher travel speeds, and (3) a system like the previous one where the hazard lights also flash (outside the vehicle) after a set period of noncompliance. The third system was considered the most invasive. Due to the uncertainty of the actual effectiveness and cost of such systems, the study presented a matrix of results for systems 10 percent to 40 percent effective, in 10 percent steps and for systems costing $25–$65 per device.

Overall, Fildes’ study showed that the benefit-cost ratios (BCRs) varied significantly. Retrofitted safety belt reminder systems at the driver position would only be worthwhile if the device costs no more than $35 per vehicle and a minimum of 20 percent improvement were expected. Alternatively, the device would be worthwhile if a 30 percent improvement were expected and the devices cost less than $45 at both the driver and passenger positions. The methodology used to estimate BCRs contrasted the expected reduction in HARM (Hazard Assessment Rating Methodology, a metric used to characterize the number and severity of injuries sustained and overall cost to society) with the anticipated costs of such devices.

Fildes’ study identified that safety belt reminders are most appropriate for those who forget to put their safety belts on rather than for those who actively refuse to use them. The study further found that safety belt reminders could be introduced as add-on devices and would not require major restructuring for passenger vehicles.

In 2002, Williams, et al. investigated the “Effectiveness of Ford’s BeltMinder System in Increasing Seat Belt Use.” The study observed 2,334 drivers of model year 1998–2002 passenger cars, both those equipped and those not equipped with the Ford BeltMinder system.

Williams’ study presented findings of observed usage rates for 1,521 non-BeltMinder-equipped Ford vehicles compared with safety belt usage rates for 813 BeltMinder-equipped vehicles. The study identified that the audible reminder chimed for 6 seconds, paused for 30 seconds, and repeated for up to 5 minutes if a front-seat occupant was present and unbuckled while the engine was started or if the vehicle was traveling more than 3 mph (differences existed based on the electronics of the vehicle). The study reported differences in safety belt use rate by vehicle type and driver gender. Table 1 summarizes the overall results of the evaluation and shows that a 3 percent higher safety belt use rate was observed for male drivers of cars and minivans equipped with a BeltMinder system compared to those vehicles without the BeltMinder system. A 5 percent higher safety belt use rate was observed for female drivers of cars and minivans with the BeltMinder system. For male pickup truck drivers, an 8 percent higher safety belt usage rate was observed with the BeltMinder system, and for female pickup truck drivers a 4 percent increase in safety belt use was observed. For male SUV drivers, a 4 percent increase in safety belt use was observed with the BeltMinder and an 8 percent higher safety belt use rate was observed for females driving SUVs.

A second study by Williams, et al. (2003) studied drivers' opinions of Ford's BeltMinder System. The goal of the study was to determine consumer reaction to the Ford BeltMinder System implemented in passenger vehicles and to compile self-reported safety belt use information as it related to the technology. Personal interviews of 405 drivers of vehicles with the reminder system were conducted at Ford dealerships.

Table 1. Observed Safety Belt Use With and Without the Ford BeltMinder System

Vehicle Type/ Driver Gender	Driver Gender	No Reminder	Reminder	Difference	95% Confidence Interval
Car/minivan	Male	74	77	3	–3.5 to 10.4
Car/minivan	Female	81	86	5	–1.9 to 11.0
Pickup	Male	58	66	8	–1.0 to 17.0
Pickup	Female	72	76	4	–16.9 to 24.9
Utility Vehicle	Male	68	73	4	–6.7 to 15.2
Utility Vehicle	Female	76	84	8	–3.1 to 18.8

Overall, Williams' 2003 publication stated that 73 percent of the respondents who experienced the reminder said that they buckled up as a result. Of those who did not buckle up, 58 percent ignored the noise, whereas 21 percent deactivated the system. Five percent of all respondents used methods described in the owner's manual to permanently disable the system. In terms of the effect of the safety belt systems on behavior, 52 percent said that their safety belt use remained the same after the system was added, 46 percent said that they used safety belts more, 30 percent said that they used the safety belts much more, and 2 percent claimed lower safety belt use. When asked if they like the systems, 78 percent said yes, 18 percent said no, and 4 percent were undecided.

Howell, et al. (2003) conducted a study for the Transportation Research Board and published "Special Report 278: Buckling Up: Technologies to Increase Seat Belt Use." The study summarized an examination of the potential benefits of technologies designed to increase safety belt use in passenger vehicles as requested by Congress. The study also determined how passenger vehicle drivers view the acceptability of the technologies, and it considered whether legislative or regulatory actions were necessary to enable their installation on passenger vehicles.

Howell's study outlined reasons for part-time and habitual nonuse of safety belts based on NHTSA studies, including the Motor Vehicle Occupant Safety Survey (MVOSS) and the National Occupant Protection Use Survey (NOPUS). The study also provided a historical review of experiences with safety belt use technologies, including light and buzzer reminders (1972), ignition interlocks (1973), and the 4- to 8-second warning light and buzzer system.

Howell's study found that audible reminder systems are effective and acceptable to passenger vehicle drivers. The technology is proven and reliable. Also, existing passenger vehicle technology (including safety belt buckle sensors and existing chimes) allows for simple implementation of an enhanced audible reminder. Final study recommendations included the following:

- Congress should amend the statute regarding safety belt reminder systems by lifting the restrictions on systems with lights and chimes longer than eight seconds, which would provide NHTSA more flexibility and the authority to require effective safety belt reminder technologies.
- Every new light-duty vehicle should have as standard equipment an enhanced safety belt reminder system for front-seat occupants with an audible warning and visual indicator that are not easily disconnected. Any auditory signal should be audible above other sounds in the vehicle. For the short term, manufacturers should be encouraged to provide these systems voluntarily.
- NHTSA should encourage the industry to develop and deploy enhanced safety belt reminder systems in an expeditious time frame, and NHTSA should monitor the deployment. As differences in effectiveness and acceptability of safety belt reminder systems are identified, manufacturers should install systems that are determined by empirical evidence to result in the greatest degree of effectiveness while remaining acceptable to the general public. Should voluntary efforts not produce sufficient results, NHTSA should mandate the most effective acceptable systems as determined by the current data.
- Rear-seat reminder systems should be developed at the earliest possible time, as rear-seat sensors become available.
- NHTSA and the private sector should strongly encourage research and development of safety belt interlock systems for specific applications.
- Safety belt use technologies should be viewed as complementary to other proven strategies for increasing safety belt use, most particularly the enactment of primary safety belt use laws that enable police to pull over and cite drivers who are not buckled up and well-publicized enforcement programs.
- Congress should provide NHTSA with funding of $5 million annually to support a multiyear program of research on the effectiveness of different enhanced safety belt reminder systems.
- In 2008, another independent review of safety belt use technologies should be conducted to evaluate progress and to consider possible revisions in strategies for achieving further gains in safety belt use, including elimination of the statutory restriction against NHTSA's requiring vehicle interlock systems.

In 1980, Geller, et al. published a study titled “Safety Belt Use in Cars with Starter-Interlock and Buzzer-Light Reminder Systems,” which described an observational study performed at a large southeastern university to understand the relationship between device intrusiveness and safety belt wearing rates for passenger vehicles. A total of 1,827 drivers were observed during entry and exit at Virginia Tech University, and a subset of these drivers agreed to complete a questionnaire regarding their safety belt use behavior.

Geller's study identified overwhelming rates of disabling or defeating the interlock or continuous buzzer systems—62 percent of those interviewed disabled the systems. Of those who disabled the system, only 15.9 percent of the drivers buckled up. Of the remaining drivers with working interlocks or continuously sounding buzzers, all buckled up. The study concluded that unlimited buzzer systems would be optimal if methods to prevent defeating them were put in place.

A study by Bentley, et al. (2003) found that the entertainment system interlock, as well as previously implemented transmission interlocks, crossed the line of "acceptable" devices to increase safety belt use.

2.3. GENERAL SAFETY BELT INFORMATION: CMVS AND PASSENGER VEHICLES

Preece, et al. (2002) published a study titled "Seat Belt Use by Heavy Truck Drivers—A Simple Way to Save Lives," which was presented at the National Heavy Vehicle Safety Seminar held in Melbourne in October 2002. The objective of the study was to summarize three research studies commissioned by the Roads and Traffic Authority of New South Wales. The data sources include interviews with seven drivers (nonusers), case data from 205 crash events, and an observational study of 1,488 vehicles for safety belt use.

The research topics summarized in Preece's study included the attitudes and knowledge of truck drivers regarding safety belt use. These include restriction in the use of side mirrors, discomfort during normal driving with suspended seats and safety belts that lock, inconvenience when performing deliveries, impeding ability to move or escape to avoid injury after a collision, difficulty accessing and unlocking safety belt, and getting entangled in the safety belt when exiting the cabin.

Preece, et al. noted that these reasons cited for nonuse of safety belts are similar to those raised by drivers of light vehicles before the introduction of compulsory safety belt use. The authors estimated that between 40 percent and 50 percent of fatalities can be prevented by safety belt use, based on their crash vehicles study data involving 205 crash events. They also cite effectiveness estimates from other sources; for example, Campbell and Sullivan (1991) estimated that between 27 percent and 77 percent of truck driver fatalities could be prevented with safety belt use.

Finally, Preece's study collected the observed safety belt use from roadside vantage points and vehicle inspection stations. Some 1,488 vehicle drivers were observed; 32 percent of these reported wearing a lap-sash safety belt, 30 percent had the lap-sash safety belt available but were not restrained, and 37 percent had a lap-sash safety belt available, but the level of use was unknown. Results were presented by seat position and truck type.

Huey, et al. (2005) published a technical report for NHTSA that identified "Shoulder Belt Usage by Commercial Motor Vehicle Drivers." This study reported the findings of an observational study identifying shoulder safety belt usage rates by drivers of Class 7 and 8 vehicles. The goal was to collect a convenience sample of safety belt use data to identify changes that have occurred since the 2002 study was completed. The study identified issues related to the direct observation of safety belt use that would also hinder the enforcement of a mandatory safety belt use law. Data were collected over a six-week period at rest areas, truck stops, and exit ramps on or near limited access highways, as well as at intersections. Thirty observations at 10 sites were targeted per state (i.e., 300 total per state). The study report went into great detail regarding site sampling methods, observational procedures, and management strategies.

Overall, the results of the Huey study were based on the observation of 4,740 trucks (compared to 3,909 in 2002). Truck stops/rest areas accounted for 46 percent of the observations, 38 percent were at signalized intersections on primary highways, 10 percent were on interstate exit/entrance ramps, and 6 percent were at signalized intersections on secondary highways.

Table 2 shows Huey's findings by vehicle type and class of truck for the 2002 and 2005 studies. Higher use rates were observed for major U.S. or regional companies. Of their drivers, 63 percent were belted versus 41 percent for independent and local fleets. The authors suggested that educational programs and company policies may be used by many of the major carriers and may be the reason for higher use rates among their drivers. Similarly, higher use rates were confirmed for hazmat vehicle operators across all trailer types (75 percent use for hazmat vehicle operators and 54 percent overall for nonhazmat vehicle operators).

Table 2. Observed Belt Use by Trailer Type in Class 7 and 8 Trucks

Trailer Type	Survey Year 2005 (%)	Survey Year 2002 (%)
Single Van	62	51
Single Tanker	75	61
Single Dump	23	26
Doubles, All Types	59	56
Bobtails	40	33
All Class 8	54	47
All Class 7 and 8	54	48

Source: Huey, et al. (2002, 2005).

Observational safety belt use results reported by Huey, et al. (2006) showed that 59 percent of Class 7 and 8 drivers were wearing safety belts in 2006, up from 54 percent in 2005. Federal Motor Carrier Safety Regulations require CMV drivers to wear safety belts. For truckers driving for national or regional fleets, the use rate increased to 75 percent in 2006, up from 63 percent in 2005. Independent drivers' buckled-up rates increased in 2006 to 44 percent, compared with 41 percent in 2005. As previously mentioned, the study was a convenience sample observing safety belt use by Class 7 and 8 truck drivers. Currently, there are no published data describing safety belt use rates for truck drivers of Class 4 to 6 vehicles.

Simon, et al. (2001) submitted a paper entitled “Potential Gain to be Achieved by Generalization of Seat Belts and Airbags in Trucks” to the 17th International Technical Conference on Enhanced Safety of Vehicles in the Netherlands. The study reviewed 403 accidents involving unbelted drivers of large trucks in France. Injury mechanisms were considered to calculate the expected benefits to large truck occupants if they were belted and, separately, if they were airbag-protected. The effect of the presence of the airbag in preventing fatalities was estimated to be minor relative to the effect of safety belt use.

Simon calculated a surrogate for crash severity (EES and deltaV) based on crash investigation data and vehicle parameters. Individual case reviews were conducted to code the relative differences in injury severity that are likely with safety belt use. Case reviews were also conducted to estimate whether an occupant would have sustained his or her injuries if he or she had been belted. Injuries to each body region were classified in one of three categories: (1) intrusion of vehicle components or external objects, (2) projection of the occupant within the vehicle cab, and (3) ejection of the occupant from the vehicle cab. Crash types, crash severity (violence), and injury mechanism were considered. The study defined crash conditions that would and would not be affected by safety belt use, compiled data, and performed logistic regression to estimate injury and fatality risk changes with and without safety belts.

Simon’s study summarized findings of other studies indicating that truck safety belt systems are 50 percent to 60 percent effective in preventing injuries and 22 percent effective in preventing fatalities. In Europe, safety-belt-wearing rates were self-reported at 12 percent, whereas observed rates are at 1.5 percent in France and less than 5 percent in Germany. Sixty percent of crashes involving large trucks would not be affected by safety belts (i.e., side impacts and rear impacts). The crash types selected that would be affected by the use of safety belts were: (1) frontal crashes with another vehicle, (2) single-vehicle frontal crashes with a fixed object, and (3) rollover and tipover crashes. The most frequent injury cause was occupant excursion from a seated position, followed by contact with interior components, whereas intrusion and ejections led to the most serious injuries. The study identified that safety belt use (plus an airbag) would be effective in preventing 37 percent of the fatalities, 36 percent of serious injuries, and 22 percent of the slight injuries.

A study by Siegmund, et al. identified a 26 percent to 37 percent increase in head, thoracic, and pelvic accelerations and a 20 percent to 54 percent increase in neck loads and moments of the addition of 10 centimeters of slack to a safety belt system. Most commercial vehicles do not come equipped with pretensioning retractors. Ideally, a safety belt system should closely couple an occupant to the decelerating vehicle structure as early as possible during a crash event. If additional slack exists in the system, the safety belt does not decelerate occupants for as long a period of time before the vehicle structure comes to rest. In this case, an occupant will experience a higher deceleration force over a shorter period of time before he or she is brought from precrash speeds to rest.

NHTSA amended the passive restraint requirement calling for safety belt ignition interlocks in all 1974 model year vehicles. Although immediate increases in safety belt use rates were documented by NHTSA as a result of the ignition interlock requirement (30 percent reported by Robertson in 1975), considerable public opposition to the technology requirement led to amended legislation prohibiting ignition interlocks and continuous audible safety belt reminders that same year. A less aggressive requirement was introduced in 1975 calling for a warning light to be displayed for 4 to 8 seconds and for a chime to sound until safety belts were buckled or eight seconds had passed. This is still a requirement for passenger vehicles. No such NHTSA requirement exists for CMVs.

A 1995 study by Kratzke summarized the "Regulatory History of Automatic Crash Protection in FMVSS 208," and outlined the history of the Federal Motor Vehicle Safety Standards (FMVSS) occupant protection requirements since safety belts were first introduced in passenger vehicles in 1968. One portion of the paper describes the U.S. experience regarding mandatory ignition interlocks. In August 1973, all new cars were required to be equipped with automatic protection (like airbags) or with an ignition interlock for both front outboard seating positions. With few exceptions, all 1974 model year vehicles met the requirement. The study described public resistance to safety belt-starter interlock systems and suggested that methods to disable the systems were being widely disseminated and applied by users. The devices were introduced at a time when the benefits of safety belts were not widely known. In addition, new safety belt interlock systems did not work well technically and were prone to fault. On October 27, 1974, a law was passed that prohibited any Federal motor vehicle safety standard from requiring or permitting the use of any safety belt interlock system.

3. TECHNOLOGIES EXPLORED

A review was conducted to identify previously implemented technologies, current systems in vehicles, and possible future systems that could increase safety belt use by CMV drivers. A basic description of all known safety belt technologies is presented in this section. Information sources include published data from the scientific literature, ideas proposed by industry stakeholders, and concepts under development by truck original equipment manufacturers (OEMs) or restraints manufacturers. In addition, an Internet search was conducted to identify any additional systems not discovered during a review of the above sources.

3.1. SAFETY BELT SYSTEMS CURRENTLY AVAILABLE IN LARGE TRUCKS

This section describes, in general, safety belts, reminder systems, and comfort devices currently available in CMVs sold in the United States. This information was compiled based on findings of the literature review presented in Chapter 2, through informal discussions with large truck OEMs, restraint suppliers and aftermarket device manufacturers, and based on data supplied by the Truck Manufacturers Association (TMA).

3.1.1. Safety Belts

In general, U.S. trucks are equipped with three-point safety belt systems; however, only two-point safety belts are required by the U.S. Code of Federal Regulations, Part 571, FMVSS Number 208. The standard requires the installation of either two-point lap safety belts (Type I) or three-point lap shoulder restraints (Type II) at each outboard seating position in vehicles with a GVWR of 10,001 pounds or more. Due to frontal barrier crash requirements for these vehicles, most, if not all, manufacturers of large trucks choose to install three-point safety belts in order to meet the standard. In some specialized vehicles in which cab configuration does not lend itself to a B-pillar mounted D-ring, two-point safety belts may be installed for practical reasons. For passenger vehicles (weighing 10,000 pounds or less), Type II safety belts are required and Type I safety belts are not permitted as an option.

3.1.2. Audible and Visual Reminders

Currently, no Federal regulations require safety belt reminder systems of any kind (audible or visual), for vehicles with a GVWR of 10,001 pounds or more.

A passive visual reminder system is one that illuminates a safety belt icon or a dash warning lamp for a finite period (usually 5–15 seconds) without actively sensing if the safety belt is buckled. Similarly, a passive audible reminder would chime or buzz for a set period of time without sensing if safety belts were fastened. After this period, the visual or audible system would shut off even if a driver had not fastened his/her safety belt.

An active visual reminder would illuminate continuously or flash until safety belts are buckled. Typically, active systems use buckle sensor information to determine safety belt use status. An active audible reminder would chime continuously or intermittently until the buckle sensor or other data indicate that a belt has been fastened.

It should be noted that passenger vehicles weighing less than 10,000 pounds GVWR are required by NHTSA to have active technologies to remind drivers to buckle up when the vehicle is first started. *No such requirement exists for vehicles weighing 10,001 pounds GVWR or more*. The U.S. Code of Federal Regulations, Part 571, Federal Motor Vehicle Safety Standard Number 208 states that for passenger vehicles, "The driver's seating position shall be equipped with a warning system that, at the option of the manufacturer, either—activates a continuous or intermittent audible signal for a period of not less than four seconds and not more than eight seconds and that activates a continuous or flashing warning light visible to the driver displaying the identifying symbol for the safety belt telltale, or, at the option of the manufacturer if permitted by FMVSS 101, displaying the words 'Fasten Safety Belts' or 'Fasten Belts,' for not less than 60 seconds when the vehicle's ignition switch is moved to the 'on' position or to the 'start' position and the driver's safety belt is not in use. Safety belt use is determined, at the option of the manufacturer, either by the safety belt latch mechanism not being fastened, or by the safety belt not being extended at least four inches from its stowed position" (*Federal Register*, 1974).

Some manufacturers of large trucks have begun voluntarily equipping their vehicles with passive reminder systems (visual and audible), and some are voluntarily equipping vehicles with active systems (e.g., dash warning lights/telltales or audible reminders) that use a buckle sensor to determine safety belt use status. As suggested by the data in Table 3, smaller CMVs (Class 3–Class 6) are more often equipped with passive and active reminder technologies compared with Class 7 and 8 vehicles. It is likely that instrumentation and safety systems for these vehicles are shared with other platforms weighing less than 10,000 pounds, where safety belt warning systems are required by FMVSS.

As shown in Table 3, some 40 to 60 percent of Class 3 vehicles are equipped with active safety belt reminders. Virtually no Class 8 vehicles manufactured in 2006 are equipped with active systems.

Table 3. Estimated Sales of Large Trucks Equipped with Active and Passive Safety Belt Reminders

Vehicle Class	Annual Production in 2006[1]	Estimated Number of Model Year 2006 Vehicles With Passive Safety Belt Reminders (%)	Estimated Number of Model Year 2006 Vehicles With Active Safety Belt Reminders (%)
Class 3 (10,001–14,000 pounds GVWR)*	150,000	75–85	40–60
Class 4 (14,001–16,000 pounds GVWR)*	50,000	60–80	30–50
Class 5 (16,001–19,500 pounds GVWR)*	49,000	60–80	15–35
Class 6 (19,501–26,000 pounds GVWR)	70,000	50–70	Fewer than 5
Class 7 (26,001–33,000 pounds GVWR)	91,000	30–50	Fewer than 2
Class 8 (33,001 or more GVWR)	284,000	30–50	Near 0

[1] Based on truck sales data from Wards Automotive Group. Source: The Truck Manufacturers Association (TMA) supplied data and dealership reviews. TMA represents all of the major manufacturers of medium and heavy trucks over 19,500 pounds GVWR in the United States. Data for all weight classes are approximate based on information available.

Table 3 provides estimates of new vehicle sales with active and passive safety belt reminder systems. These data were supplied, in part, by TMA, where member companies reported sales percentages with and without the systems. At the request of the manufacturers, individual company percentages are not reported. TMA member companies include Ford, Freightliner, GM, International, Isuzu, PACCAR-Peterbilt/Kenworth, and Volvo/Mack.

Addition information not supplied by TMA was gathered by the research team through new-vehicle dealer interactions and through direct observation of vehicles in service.

In general, passive visual reminder systems illuminate for a period of 5 to 15 seconds. The duration varies by manufacturer. Passive systems do not sense if a safety belt is fastened but simply illuminate for a predetermined period of time and then shut off. These systems do not require a buckle switch or safety belt spool-out sensor in order to operate.

In Europe, the Swedish heavy truck manufacturers Volvo Trucks and Scania have developed enhanced audible reminders that became available as options in their vehicles in 2006. This change occurred due to pressure from the European Commission and the Swedish Road Administration, which are considering legislation of enhanced audible reminders for large trucks. In addition, some large European carriers have requested that the truck manufacturers make enhanced audible reminder systems available when purchasing new vehicles. The systems are tailored for large-truck applications where they become active (chime) when the vehicle speed reaches 30 kph and chime intermittently until safety belts are fastened.

3.1.3. Comfort Devices

Currently, the majority of new Class 8 trucks sold in the United States are factory-equipped with safety belt tension adjustors more commonly known as the Komfort Latch System (see section 3.2.2 for a more detailed description of the devices). These devices are sold by the largest supplier of safety belts for large trucks. Based on this study, the research team estimated that 50 percent to 75 percent of the new Class 8 vehicles sold in the United States have the devices. These devices are not aftermarket systems. Rather, OEMs may choose to equip all units sold for a particular model line with the Komfort Latch. For other models, no Komfort Latch is installed. The devices do not appear to be common features in Class 7 and smaller vehicles. Without more detailed supplier information, it is difficult to estimate how many of these systems exist in large trucks today. It should be noted that the Komfort Latch System is designed to improve comfort by allowing the driver to introduce a variable amount of slack into the safety belt system. This reduced tension may help drivers achieve a more comfortable fit for safety belts; however, the introduction of slack into the safety belt system may also degrade the effectiveness of the restraint system.

Seat-integrated safety restraints are another technology that could improve the comfort of safety belts for large-truck operators (see section 3.2.2.3 for more detailed discussion). In the United States, seat-integrated safety restraints are not sold as standard or optional features in Class 7 or Class 8 trucks. However, seat-integrated safety restraints are now being sold as optional equipment in a small number of school bus platforms, as reported by vehicle OEMs. Seat-integrated safety restraints are more commonly available in Europe and Australia. A 2005 report by the Australian National Transport Commission estimates that 23 percent of 2004 model year trucks sold in Australia weighing 3,500 to 28,000 kg have suspension seats and seat-integrated safety belts.

3.2. TECHNOLOGIES REVIEW

In total, 13 technologies were identified that might increase safety belt use by CMV drivers. This section provides a general description of each device including aftermarket cost information if available. In addition, a picture of each technology is provided, when available.

Technologies were identified that promote the use of safety belts: (1) by providing a reminder to drivers to buckle up, (2) by facilitating enforcement of safety belt use laws or corporate policies, and (3) through improved comfort of safety belt systems. The devices considered are as follows:

1. Reminder Systems
    - Dash Warning Light/Telltale (Passive System)
    - Intermittent Dash Warning Light/Telltale (Active System)
    - Audible Reminder (Passive System)
    - Enhanced Audible Reminder (Active System)
    - Transmission Interlock System
2. Comfort Strategies
    - Safety Belt Tension Adjustors
    - D-Ring Height Adjustors
    - Seat-Integrated Safety Restraint System
    - Safety Belt Covers
3. Enforcement Strategies
    - Brightly Colored Safety Belts
    - Onboard Data Recorders
    - Exterior Safety Belt Use Indicator
    - Driver Monitoring Stickers

3.2.1. Reminder Strategies

Dash Warning Light/Telltale (Passive System)

This device would provide a visual reminder to drivers to buckle up at the start of each trip. A passive system similar to those in many passenger vehicles today would illuminate if the ignition were placed in the "on" position and would shut off after a predetermined time period had passed. Currently, a number of CMVs are equipped with systems that illuminate for periods between 5–15 seconds. The telltale most often used in vehicles equipped with visual systems is a graphic showing a belted occupant. For passenger vehicles, FMVSS 208 requires that a visual reminder system illuminate for at least 4 seconds, but no more than 8 seconds, when the vehicle ignition is placed in the "on" position (*Federal Register*, 1974). This requirement does not apply to vehicles weighing 10,001 pounds or more. No definitive cost data were available for this technology; however, manufacturers have estimated that the technology might cost $5–$10 to implement in a vehicle not equipped with the system.

Intermittent Dash Warning Light/Telltale (Active System)

An active dash warning light would operate similarly to the simple dash warning light or telltale system; however, the system would continue to illuminate or flash until safety belts were fastened. Unlike the baseline technology described above, this system would require sensing of safety belt use and would not turn off after some nominal time period. These enhanced systems currently exist in most passenger vehicles and in some medium-duty trucks. As presented in section 4.1 of this report, these systems are not commonly installed in Class 7 and 8 vehicles. The system would require sensors to determine if the safety belt was fastened. This could be a simple buckle switch or a safety belt payout sensor to identify if a safety belt has been extended from its stowed position. In addition, added wiring and some logic programming would be required. The added cost of this technology is estimated to be $75; it is available as an option from some large-truck manufacturers.

Audible Reminder (Passive System)

This device would provide an audible reminder to drivers to buckle up at the start of each trip. A passive system would chime or sound once the ignition is placed in the “on” position and shut off after a predetermined time period, much like the passive visual reminder system previously described. For passenger vehicles, FMVSS 208 requires that an audible reminder system sound for at least 4 seconds but no more than 8 seconds when the vehicle ignition is placed in the “on” position. This requirement also does not apply to vehicles with a GVWR of 10,001 pounds or more. Within a large truck, the sound created by this system must be distinguishable from other audible systems that are often active at vehicle startup. The duration of the sound should be tailored to the unique conditions within each vehicle. No definitive cost data were available for this technology; however, manufacturers have estimated that the technology might cost $5–$10 to implement in a vehicle not equipped with the system.

Enhanced Audible Reminder (Active System)

An enhanced audible reminder system would provide an audible alert for an extended period of time beyond that of the passive system. These devices would monitor safety belt use actively through buckle switches or safety belt payout sensors, and continue to provide the driver with an audible alert until the safety belt is fastened. The features of an enhanced system could be tailored, based on user preference, so that the frequency and intensity of a chime could be varied. In addition, due to the unique operating environment for large trucks, the system might be tailored to activate at a predetermined speed level and during operation of the vehicle while moving forward. One implementation of the system in vehicles manufactured by Ford, for passenger vehicle applications, chimes for 6 seconds every 20 seconds for up to 5 minutes if a front-seat occupant is present and unbuckled while the vehicle is in motion (Farmer, 2003). Other manufacturers, like Saab, have implemented systems in which intensity increases as travel speed increases. For drivers who always use safety belts, this system would not activate and could go unnoticed. The audible reminder is intended to remind front-seat occupants to buckle up in case they forget. Based on a BCA performed by the Australian government for passenger vehicles, the aftermarket cost for such a system is estimated to be $110 per vehicle (including buckle switch and wiring, onboard computer programming with safety belt use logic, and integration with an existing vehicle chime). It should be noted that some manufacturers have implemented functionality where drivers can temporarily or permanently disabled enhanced audible reminder systems. Disabling the optional Enhanced Audible Reminder System does not affect the functionality of the 4- to 8-second basic audible reminder that is required by FMVSS 208 in all passenger vehicles with a GVWR of 10,000 pounds or less.

Interlock Systems

Interlock devices have been used in the past to disable certain vehicle features if safety belt systems are not in use. Ignition interlocks prevent the engine from operating if the driver is unbelted. Transmission interlocks prevent the driver from putting the vehicle into a forward gear if the driver is not belted. Entertainment system interlocks prevent the use of certain onboard electronics, including the stereo system, CB radio, or other electronics if the safety belts are not fastened. These devices each require sensors that detect safety belt use, and they also require programming to interact with other electronic devices. As described previously, a requirement to include ignition interlocks in passenger vehicles is forbidden by law due to the unsuccessful implementation of the systems in 1974 model year passenger cars. Currently, alcohol ignition interlocks are frequently used to prevent drivers from starting their cars when their breath alcohol concentration is at or above a predetermined level. This suggests that the technology to interface with vehicle electronics is available for implementation.

3.2.2. Comfort Strategies

Safety Belt Tension Adjustors

Safety belt tension adjusters are designed to allow users to introduce some slack into safety belts to reduce abrasion and irritation against the upper body. The most readily available device, known as the Komfort Latch System, is rigidly attached at the vehicle B-pillar where the D-ring is fastened (Figure 1). The safety belt system is threaded through the plastic clip and can be locked at any position along the safety belt. In order to reduce the contact forces between the safety belt and the occupant’s upper body, a driver can introduce slack into the safety belt system. The system is activated by pulling out some desired amount of safety belt webbing and cinching the clip at any desired location. Ideally, the Komfort Latch should be fastened so that there is enough slack to eliminate safety belt contact forces, but the safety belt is close enough to occupants to effectively restrain them in the event of a sudden maneuver or a crash. The system can be disengaged by yanking on the system, and it will disengage automatically during a collision event once extended beyond the locked level. The system does not affect the activation of web-lockers or load limiters. The only difference in performance will stem from the introduction of additional slack to the safety belt system. Based on information supplied by the manufacturer, the Komfort Latch System has been sold with new vehicles and safety belt systems in more than 90 percent of CMVs sold in the United States for the past four to five years.

Figure 1. Komfort Latch System

As previously discussed, these systems are factory installed. The devices are integrated with the safety belt system and are not available as an aftermarket device. Vehicles are either equipped or not equipped by model line. If one vehicle unit is equipped with the device, all others within the same make, model, or model year will likely be equipped with the Komfort Latch System as well.

The Sliding Comfort Latch is the second generation of the Komfort Latch device. Unlike the Komfort Latch, the Sliding Comfort Latch System (Figure 2) is designed to introduce a predetermined amount of slack into the safety belt so that the user does not have to. With the first-generation Komfort Latch System, it is possible that a driver may introduce too much slack, which may defeat the purpose of the device in adequately restraining him or her in the event of a crash or a sudden maneuver. The device locks at a point based on the occupant’s amount of movement once the system is first activated. In order to activate the device, a simple “on” switch is pushed. Unlike the previous generation, the new device will only temporarily disengage during extended movements, such as adjusting the radio or reaching for distant objects, yet will re-engage once the occupants return to their initial seating position. A safety belt system equipped with the original comfort latch may become uncomfortable or annoying to the driver after movement if the system does not actively reset the device. This may lead to the overall perception that the safety belt system is uncomfortable, and possibly lead to nonuse of safety belts. Device costs are estimated to be about $35 per unit; however, retrofitting vehicles with the Komfort Latch requires complete replacement of the retractor, safety belt webbing, D-ring, and buckle system, as it is not sold separately from the whole safety belt system. The cost of complete replacement is $135–$155.

Figure 2. Sliding Comfort Latch System

Adjustable D-Ring

In order to optimize the geometry of safety belts to fit a wide variety of occupant sizes, some passenger and commercial vehicles are equipped with adjustable D-rings (Figure 3). The height of the top anchorage point can be adjusted so that the take-off point (point where the safety belt last contacts the occupant on the shoulder) can be optimized for comfort. If the D-ring is placed too low, the safety belt will come in contact with the top portion of the shoulder and in extreme cases wrap over the top. A D-ring that is placed too low may cause safety belts to fall over the shoulder joint or upper arm. This may occur for very tall drivers with low D-rings. Conversely, occupants of small stature may find the safety belt cutting across their necks and faces if the D-ring location is set too high.

In order to accommodate the introduction of an adjustable D-ring, the vehicle B-pillar must have sufficient structure to accommodate the change. If the vehicle structure is sufficient, the incremental cost for the height adjustment system is about $30 per unit.

Figure 3. Adjustable D-Ring
Source: Photo courtesy of IMMI, Inc.

Seat-Integrated Safety Restraints

Seat-integrated safety restraints (Figure 4) operate much like traditional safety belt systems; however, the upper D-ring and lower anchorage points are attached to the seat structure itself. The benefit of these systems would be to reduce the relative motion that occurs between suspended seats found in many large trucks and fixed anchorages traditionally mounted on the vehicle B-pillar and floor. With an integrated restraint, the safety belt system would travel vertically with the seat structure as it moves up and down and fore and aft during travel. Because the motion of a large-truck cab is substantially different (and larger in amplitude) than a passenger car or even an SUV or pickup, these systems could reduce contact forces and rubbing while driving. These devices are currently offered in many passenger vehicles and commercial vehicles. European manufacturers are offering seat-integrated safety restraints in their vehicles in order to improve safety belt fit and comfort for drivers. Seat-integrated safety restraint costs vary considerably; they range from $750–$1,000 per seat.

Figure 4. Seat-Integrated Three-Point Restraint
Source: Photo courtesy of Ford Motor Company.

Safety Belt Covers

Safety Belt Covers are aftermarket devices designed to reduce rubbing and irritation between the safety belt and the occupant. Most systems are either sewn in place or attached by using Velcro. The device costs $20–$30 per unit.

NHTSA does not recommend any aftermarket technology be added to a safety system as it may compromise its intended function. Safety belt covers change the interface between the belt and the occupant and may result in unfavorable kinematics of the occupant during a crash.

3.2.3. Enforcement Strategies

Brightly Colored Safety Belts

Brightly colored safety belts are a potential enforcement strategy (Figure 5). These safety belts, currently in use by some fleets, would be bright orange, yellow, or green. They would be highly visible to law enforcement and/or DOT personnel so that there would be little question whether the systems were being worn. The bright color would suggest to drivers that enforcement of safety belt use and detection of nonuse would be easier for designated officials (i.e., at inspection stations or by police).

Figure 5. Example of a Brightly Colored Safety Belt for CMV Operators

The incremental cost of this technology is estimated to be $12 over the base (noncolored) safety belt. If the entire safety belt system is purchased and installed (including retractor, D-ring, buckle system, and safety belt webbing) the estimated cost is $95–$120.

Onboard Data Recorder

Onboard data recorders may be an effective strategy to increase safety belt use if corporate safety personnel or police make use of the data. Currently, devices exist for CMVs to track location, conduct vehicle diagnostics, and plan routes. Additional functionality can be added to these systems to monitor and record safety belt use status. This information can later be downloaded or queried by designated individuals to evaluate whether a safety belt was being worn at a particular time or to understand during what percentage of travel time over a certain period that the safety belt was worn. The effectiveness of such systems relies on the perception that the data will be downloaded and used.

The estimated cost of an onboard data recorder is $2,000–$4,000 per vehicle. If safety-belt-use recording functionality is added to an existing data recorder (recording other data elements), the anticipated price increase might be $200–$300 per vehicle.

Exterior Safety Belt Use Indicator

The exterior safety-belt-use indicator light is a concept that could be effective in increasing safety belt use by CMV drivers. This device would allow law enforcement or vehicle inspectors to easily identify if a driver is unbelted. This concept was suggested by stakeholders interviewed during the study. One implementation of such a system would be to engage vehicle flashers if safety belts were not securely fastened. This approach was explored by the Australian government and was identified as a complex and costly option that would likely increase safety belt use. No cost estimates are currently available for this device.

Safe Driving Bumper Stickers

The use of safe driving bumper stickers is one approach that could facilitate enforcement of safety belt use laws and policies. Currently, stickers read by other motorists, such as: “How’s my driving? Please call 1-800…,” are commonly used to alert fleet safety personnel that their drivers may be operating in an unsafe manner. The same approach could be used where other motorists might report that drivers are not belted while driving. The use of these stickers might help drivers to realize that there is some chance that they will be caught and reprimanded if they are spotted driving in an unsafe way or driving while unbelted. A number of private companies offer services where they issue stickers for each truck, screen, and record call information for each company and report statistics to company officials. The cost of sticker purchase and service is $10–$20 for each vehicle annually.

4. STAKEHOLDER AND DRIVER PERSPECTIVES

The following summarizes the perspectives of industry stakeholders and drivers regarding each device considered:

1. Reminder Systems
    - Dash Warning Light/Telltale (Passive System): Stakeholders felt that passive visual systems that light for a short period and go out on their own would be ineffective in increasing safety belt use.
    - Intermittent Dash Warning Light/Telltale (Active System): Stakeholders felt that an intermittent dash warning light would be effective for some drivers, particularly during nighttime scenarios. Stakeholders felt the annoyance of an audible strategy would be more effective.
    - Audible Reminder (Passive System): As with the passive dash warning light system, stakeholders felt that a passive audible device could be easily ignored. This is especially true in large trucks where a number of warnings (visual and audible) are activated at vehicle startup. An audible chime could easily be lost among other alerts.
    - Enhanced Audible Reminder (Active System): The enhanced audible reminder was favored as a potentially effective strategy. Stakeholders commented that the characteristics of such a system should be tailored to large-truck applications.
    - Transmission Interlock System: The transmission interlock device was not highly favored. Stakeholders cited past experiences with such devices in passenger vehicles and were concerned that a malfunctioning system might prevent a driver from doing his or her work.
2. Comfort Strategies
    - Safety Belt Tension Adjustors: Stakeholders favored these devices, indicating that they are one of the few systems that could help drivers improve the comfort of safety belts; however, additional driver awareness is necessary to ensure increased safety belt wearing rates.
    - D-Ring Height Adjustors: Many stakeholders acknowledged that height adjustors might improve safety belt fit and overall comfort, but improved driver awareness would be necessary before the devices would lead to improved safety belt use rates. In addition, the device would only address part of the safety belt comfort issue (i.e., geometry, not the rubbing of safety belts).
    - Seat-Integrated Safety Restraint System: Stakeholders favored the concept of seat-integrated safety restraints; however, they felt that the technology requires additional comfort evaluation and might be a long-range solution.
    - Safety Belt Covers: Few stakeholders saw benefit in such systems. Some identified that comfort relates more to geometry of systems, and that a safety belt cover would not bring about improvement in this area.
3. Enforcement Strategies
    - Brightly Colored Safety Belts: Brightly colored safety belt systems were favored by stakeholders as a cost-effective strategy that could make a considerable difference.

- Onboard Data Recorders: Onboard data recorders were strongly supported by all fleet managers and trade organizations. They felt that with the introduction of electronic onboard data recorders (EOBDRs) into trucks to log hours of service, this solution might hold promise; however, implementation of an electronic recorder for the purpose of recording safety belt use did not seem worthwhile.
- Exterior Safety Belt Use Indicator: This system was thought to be potentially effective; however, it was perceived as potentially unfair to drivers.
- Driver Monitoring Stickers: Stickers were thought to be a plausible solution but were not highly favored as the ideal solution.

4.1. INDUSTRY PERSPECTIVES

Discussions were conducted with industry stakeholders, many of the members of the CMV Safety Belt Partnership, to gain insight into the safety-belt-use issue and to seek feedback regarding the viability and practicality of the various technologies described in Chapter 3. Industry perspectives were gathered during discussions with various representatives from the following organization types:

- Vehicle OEMs
- Restraint and aftermarket device suppliers
- Insurance organizations
- Commercial motor vehicle fleet safety managers
- Trade associations and government personnel

A summary of key responses by the stakeholders is provided in the following six topics.

4.1.1. Topic 1: Increasing Safety Belt Usage by CMV Drivers

- A trade organization and fleet safety manager reported similar opinions that large, well-managed fleets could successfully address safety belt use through enforcement of corporate policies. However, smaller fleets without a well-enforced corporate policy would likely respond to technologies facilitating enforcement by inspectors and police to increase safety belt use.
- A government representative indicated that some drivers may not have knowledge of the potential benefits of safety belts. Education will help, but must be delivered in a concise format that drivers can relate to. An education campaign should be assembled and widely distributed to dispel myths related to safety belts.
- A fleet manager suggested that money out-of-pocket is a serious incentive for drivers. Enforcement of company policies that could impact employment would be effective, and the threat of fines from police or inspectors for nonuse of safety belts would also help.
- A trade organization representative indicated that issues of safety belt use differ considerably with owner-operators as compared to private companies, unless the owner-operators are personally committed to their own safety, as large-fleet safety managers are.

- An industry representative suggested that owner-operators could possibly be reached through improved public awareness and education, where graphic materials and serious messages might be the most effective.
- A fleet safety manager suggested that he has noticed a shift in safety culture whereby younger drivers, who have been raised in an environment where safety belts are required, are beginning to take positions previously held by older drivers who are not habitual safety belt wearers.
- As suggested by a trade organization representative, perhaps FMCSA or other interested organizations can offer a model safety training template for companies that could easily be adapted to company specifics. Using this presentation, a company can easily and accurately educate new and existing drivers on the utility and correct use of safety devices.

4.1.2. Topic 2: Comfort Issues

- A vehicle OEM reported that he believes that there may be comfort issues for certain segments of the CMV driver population, but he also indicated that few scientific data exist describing driver anthropometry and characteristics of safety belts in trucks that make them "uncomfortable."
- A vehicle manufacturer identified that upper D-ring height is an important aspect of shoulder safety belt comfort, yet there is little demand from vehicle purchases for the installation of these devices.
- Multiple stakeholders suspected that drivers cite discomfort due to past history or as an excuse. Many stated that if users were compelled to wear safety belts, even for a short period of time, they would likely change their opinions and even develop the habit of wearing the safety belt.
- A restraint manufacturer cited that nuisance lockups are one source of discomfort from safety belt systems; however, current safety belt design requirements and the harshness of the ride make complete elimination of nuisance lockups impossible. Yet another restraint manufacturer indicated that accidental lockups seem to be reducing in frequency due to improved safety belt design.
- Several stated that the safety belt just takes getting used to, and that the basic configuration is uncomfortable for only a small minority.

4.1.3. Topic 3: Technology Types

Audible Reminder Systems

- A government stakeholder suggested that although many have stated that they would attempt to disable enhanced audible reminder systems, many part-time safety belt users would respond to systems by buckling up. An estimated 10 percent to 15 percent of drivers might truly be habitual nonusers, but little can be done to reach these people.
- An OEM representative indicated that for some applications, a reminder system may not be appropriate; for example, for drivers who make frequent stops.
- Multiple stakeholders supported this technology, indicating that the approach has been widely successful in the passenger vehicle world and would likely be successful in trucks.

- A stakeholder suggested that adding an additional audible warning that is passive (sounds for a short period and shuts off) may not be effective because of the large number of warnings and buzzers that already exist in large trucks. Field testing must be performed to put together an optimized system that would be recognized as a warning for safety belts and accepted by users.
- Manufacturers indicated that optional equipment has already been developed that calls for buckle switches/sensors, wiring of buckle to onboard systems, and programming logic to interpret safety belt use status by onboard computers. These systems would be necessary to support an enhanced audible reminder system.

Visual Reminders

- An OEM representative indicated that a visual system will likely impact nighttime drivers by reminding them to buckle up; however, this representative felt that a driver who is adamant about not wearing the safety belt could likely adapt to the light system. This stakeholder felt that an audible chime could be a more significant annoyance.
- A government stakeholder suggested that visual warnings would be more effective if they flashed rather than illuminated continuously. User perspectives should be collected using actual on-road driving scenarios.

Electronic Onboard Data Recorder

- Fleet safety managers identified that EOBDRs would be extremely valuable to enforce safety-belt-use policies, but currently proposed regulations might only require the installation of devices owned by the poorly performing companies with regard to safety. An industry-wide deployment would likely be more effective, but the economic burden that this would place on smaller fleets might not be reasonable.
- An OEM representative suggested that a system might be effective if a roadside inspector could easily see the information when he inspects the hours-of-service logs. Data could be made available using a printout or viewed on the EOBDR screen by inspectors.
- An insurance representative indicated that options like EOBDRs require follow-through at the company's headquarters. The data would be only as effective as the management is in using the data to monitor drivers. The stakeholder stated that the introduction of technology into vehicles does not ensure that it is used.
- A fleet safety manager indicated that many fleet owners fear that drivers will rebel against a recorder; however, evidence shows that few object to EOBDRs once they are in place, due to the time-saving benefits of the systems.
- A government representative felt that vehicle fleet owners have the right to add any technology they choose and should not compromise the safety of their drivers to accommodate drivers' wishes.
- Insurance advocates indicated that they are in favor of a company making use of data recorders to reward good behavior and help poor-safety performers to drive more safely. This concept suggests that fleet management could take on this task and it would be looked upon favorably by insurance companies.
- A truck fleet owner has the right to use data to protect the lives and well-being of their drivers and to ensure that their drivers are operating safely.

Brightly Colored Safety Belt Systems

- Two fleet safety managers have purchased and implemented brightly colored safety belts in their fleets and feel that these devices have made a difference in their drivers' behavior. Drivers fear enforcement by police (small fleet) and by corporate officials (large fleet).
- An insurance representative suggested that the success of brightly colored safety belts relies on the fact that specific people are looking for the safety belts, namely, police and company personnel. Others believe that the threat of enforcement also has a significant impact.

Interlock Technologies

- Stakeholders were reluctant to support interlock technologies due to the possibility that drivers would be unable to perform work if the device failed.

Safety Belt Tension Adjusters

- Two manufacturers (one OEM and one restraint manufacturer) agreed that a safety belt system with a safety belt tension adjustor would perform better if a pretensioner were installed; however, the cost of these systems might prevent them from being voluntarily introduced.
- All stakeholders from OEMs indicated that the Komfort Latch is available in the majority of their Class 8 vehicles being sold, and the manufacturer of the tension-reducing system (Komfort Latch) reports that they are sold with 90 percent of new Class 8 vehicles.
- An OEM stakeholder suggested that the use of the Komfort Latch was an acceptable interim solution until seat-integrated safety restraints were introduced. Negative stakeholder opinions were based on the introduction of slack into safety belts, which is known to degrade performance.

Seat-Integrated Safety Restraints

- Manufacturers indicated that the addition of seat-integrated safety restraints would require additional engineering for vehicle structures to meet frontal crash test requirements; however, manufacturers indicated that the redesign would be technically feasible.
- All OEM stakeholders indicated that seat-integrated safety restraints appear to be a good idea, but the only current application in the United States is in buses.
- Within the current bus applications, one OEM indicated that some complaints regarding seat-integrated safety restraint comfort have been raised because current systems are optimized for 50th percentile drivers. Development is underway to design seat-integrated safety restraints with variable upper anchorage heights to deal with this problem for smaller drivers.

Adjustable D-Ring

- A manufacturer indicated that adjustable D-ring systems were offered as an option for many years; however, the company chose to stop offering this because so few customers purchased the device.

- A restraint manufacturer suggested that safety belt comfort is a direct function of optimal seat and D-ring geometry. He expressed the thought that an adjustable D-ring is a promising device to achieve comfortable geometry, but few drivers understand or make use of the systems.
- A fleet safety manager indicated that they do not have or offer any training to instruct drivers on safety belt adjustment for optimal comfort. The representative suggested that his organization does not have any clear guidelines to offer and also pointed out that only a handful of his vehicles are equipped with an adjustable D-ring system anyway.

4.1.4. Topic 4: Integration and Footing the Bill

- A trade organization representative and a number of vehicle manufacturers suggested that safety technologies are not likely to be added without demand from purchasers or regulatory requirements for their installation. This is the case because truck pricing is very cost-competitive.
- Very few manufacturers will voluntarily begin adding a new device, due to the added cost. Additional technology would put them at a competitive disadvantage. However, if a requirement were in place, manufacturers would not complain.
- A private fleet installed brightly colored safety belts and found their inclusion in vehicles made a considerable difference, along with good safety practices in observing drivers. Costs were absorbed by the company to retrofit some vehicles in the 500+ vehicle fleet, while other systems were introduced during new vehicle phase-in. Another fleet safety manager indicated that he purchased new bright orange safety belts at an added cost of $12 per unit for his 17-vehicle fleet. Retrofitting vehicles would cost $110 per truck.
- Manufacturers indicated that all technologies under consideration are technically feasible and could be easily added if there was regulatory or consumer demand for the products. One manufacturer suggested that recent CAFE (corporate average fuel economy) requirements will likely lead to faster introduction in new trucks, so that integration of new technology in these vehicles could occur very quickly.
- Insurers indicated that they are not likely to offer rate incentives for the implementation of a safety belt technology. Rather, insurance rates are typically based on past performance in terms of crash involvement, injuries, and fatalities.
- Insurers look more favorably on fleets that have put emphasis on safety in general rather than implementing a single device. A rate reduction might be factored in if a company demonstrated a total commitment to safety.
- As indicated by one insurer, large fleets often purchase insurance with large deductibles ($1M, $2M, etc.), so their insurance premiums remain low. For this reason, crash costs due to property damage and injury are often first absorbed by the trucking companies.
- A trade organization suggested that any company that is not willing to implement a mandatory safety-belt-use policy is not serious about safety.
- Owner-operators should have to follow safety guidelines set by the companies they work for. There is an opportunity at the contracting phase to include mandatory use of safety belts in the contract.

4.1.5. Topic 5: Corporate Safety Belt Policy

- A small fleet safety manager (fewer than 25 trucks) has successfully implemented a program known as Pay for Performance in which financial rewards are offered quarterly for good performance. Drivers are rewarded with a $0.02 increase per mile for any quarter where no violations occurred. If they receive a citation or are involved in a preventable crash, a portion of the reward is removed. At the end of each year, rewards are given for good safety performance throughout the year. This fleet safety manager strongly supported using EOBDR information (regarding safety belt use) in the future as one factor used to offer rewards.
- A fleet manager whose drivers are primarily hauling hazmats described their safety-belt-use policy as a last-resort policy where any driver who is cited, caught, or involved in a collision while unbelted is fired. The policy appears to be very effective; however, multiple strategies were simultaneously applied (added education and bright safety belt strategies) to bring about the change in behavior. This change was made after a number of serious injury crashes occurred in which safety belts were not used.
- A fleet safety manager explained that they used a “three strikes, you’re out” policy in which drivers are fired if they are involved in or cited for more than three safety-related violations within a two-year period. These instances include being in a preventable crash, receiving a ticket/DOT citation of any kind, or being spotted by management or other personnel while unbelted or involved in any other unsafe driving acts. This fleet manager admitted that management of this company rarely performed dedicated observations or cited drivers for observed unsafe behaviors.

4.1.6. Topic 6: Other Strategies to Increase Safety Belt Use by CMV Drivers

- A fleet safety manager described a recent statewide policy that requires certification of drivers for homeland security applications before a commercial driver’s license (CDL) is issued, and suggested that a safety module could be added during the online certification process. This approach might work if an online or written safety belt course were also required before allowing a CDL renewal.
- Multiple stakeholders, including trade association representatives and insurance representatives, stated that they believed that drivers’ wearing of safety belts is the responsibility of the fleet owner/manager, and that companies should implement any strategy or technology they feel would protect the well-being of their drivers, regardless of any perceived threat of driver disapproval.
- A trade organization representative suggested that inconspicuous cameras or observations from an inspection station might help to identify drivers before they buckle up. The perception that higher levels of enforcement exist might result in increased safety belt use.
- Two fleet safety managers indicated that they successfully use driver safety stickers (How’s My Driving? Please Call 1-800-….) to monitor driver behavior. If a concise message could be written to request a call if drivers are spotted driving unbelted, this might also help to promote safety belt use.

4.1.7. Stakeholder Discussion Summary

The stakeholders collectively emphasized the importance of CMV drivers wearing safety belts. For the most part, they showed a common perspective on all of the issues raised. In general, the participants agreed that more education about the benefit of safety belts and the safety belt technologies that are currently available or in use would increase the safety belt use rates. It was felt that large and well-managed fleets could increase safety belt use with enforcement, but that smaller fleets would likely find it necessary to rely on inspectors and police. In general, stakeholders indicated that the common reason for not wearing the safety belt (comfort issue) was based on past history or that it was used as an excuse.

Several technologies were discussed with the stakeholders and the majority of the opinions were similar. They indicated that the audible reminder worked well in passenger vehicles, but it would likely not be as effective for drivers who make frequent stops. Visual reminders were thought to be more effective at night and perhaps even better if they flashed when activated. An industry-wide deployment of the EOBDR would be more effective, but the economic burden on smaller companies would probably be unreasonable. This technology was favored by insurance companies.

Brightly colored safety belts are currently used in some fleets, and it is believed that the fear of enforcement makes this device effective. Interlock technologies were unfavorable because a driver may not be able to carry on with work if the device fails. Safety belt tension adjusters are currently widely available, but the introduction of too much slack is a concern. Manufacturers indicated that seat-integrated safety restraints would require additional testing to meet frontal crash test requirements. The adjustable D-ring is a favored device, yet there is no training for drivers to receive optimum comfort.

The integration of technologies to increase safety belt use in CMVs and the financial concerns of doing so were discussed. It was indicated that manufacturers are not likely to add safety belt technologies unless there is a demand from purchasers or unless regulatory requirements exist that would keep pricing competitive. The discussion also indicated that all of the technologies discussed were technically feasible. Insurers indicated that they are not likely to offer incentives for safety belt technology, as their incentives are typically dependent upon past performance records. However, if safety belt reminder systems or other approaches begin to have a measurable positive safety impact, it would be possible that a reduction in insurance costs might be realized with the introduction of this safety feature.

Rewards and penalties are both used in corporate safety-belt-use policy. Financial rewards are offered quarterly for good performance in one participant’s company, whereas another company will fire an employee who is not belted when involved in a collision; yet another company gives the employees three strikes before they are terminated for not wearing their safety belts.

Discussion participants were asked for other strategies to increase safety belt use, and the most common response was to offer more education about safety in general and the safety belt technologies offered in their fleets. Bumper stickers asking for violations to be reported and inconspicuously placed cameras were suggested as methods of enforcement. Numerous stakeholders believe that wearing a safety belt is the responsibility of the fleet owner/manager, regardless of the threat of driver disapproval.

4.2. DRIVER PERSPECTIVES

Based on information gathered during the literature review and through interaction with industry stakeholders, several promising technologies were selected for further review. To better understand opinions of drivers regarding the practicality and potential usefulness of these devices, the research team conducted various discussions with drivers. The discussions were held to evaluate aspects of new safety belt technologies such as perceptions of proposed technologies, including the benefits, unforeseen pitfalls, and the acceptance or rejection of these by CMV drivers.

Discussions were conducted with CMV drivers regarding current safety belt use and nonuse, and safety belt technologies. Both nonusers of safety belt and safety belt users were involved in these discussions. The drivers talked about their beliefs on the efficacy of safety belts, personal safety belt use (current and past), safety belt comfort, seat enforcement, and personal freedoms. Also discussed were the following:

- Safety belt tension adjustor: Komfort Latch
- Seat-integrated safety belts (three-point)
- Seat-integrated safety belts (four-point)
- Enhanced audible reminder
- Dash warning light
- Vehicle transmission interlocks
- Entertainment system interlocks
- Heating and cooling system interlocks
- Onboard data recorders
- Exterior safety belt use indicator light
- Brightly colored safety belts
- Safety belt monitoring by transponder at weigh stations

The topics of discussion varied. The key findings, observations, and impressions received regarding the various issues are presented as follows:

1. Improving Safety with Safety Belts
2. Safety Belts in CMVs versus Passenger Vehicles
3. When Safety Belts Are Used
4. Why Safety Belts Are Used
5. Safety Belt Comfort
6. Safety Belt Enforcement
7. Twelve Technologies to Increase Safety Belt Use

4.2.1. Topic 1: Improving Safety with Safety Belts

There is a perception among nonusers of safety belts that wearing safety belts in trucks can be potentially harmful. Nonusers of safety belts provided anecdotal stories of people who would have been killed had they been wearing a safety belt. Another prevalent perception is that wearing a safety belt would prevent a driver from being able to quickly move out of harm’s way if his or her load was shifting or if a crash was impending. They felt there would be sufficient time to move to a safer portion of their cab or jump safely out of the vehicle if unbelted. There are also fears of being trapped in rollovers and intrusion from behind.

Among the safety belt users, most agreed that safety belts make you safer. Two reported being saved by safety belts and one reported starting to wear a safety belt after seeing another driver thrown from his truck, which rolled on top of him. However, many of the consistent safety belt users felt that there were situations in which safety belt use could hurt a driver.

Observations and impressions on whether safety belts improve safety include the following.

Nonusers of Safety Belts

- There is an overall feeling that safety belts would be useful in about 50 percent of crashes, and that this varies by accident.
- The biggest driver concern during crashes is intrusion, where the engine, steering, or dash could get pushed into the compartment.
- Personal stories were told identifying experiences in which people survived with no safety belt.
- There is an overall belief that the safety belt increases the chances of injury.

Safety Belt Users

- There is a fear that the safety belt might injure the chest.
- An unbelted driver who had been in a rollover was ejected from the cab and was pinned. He wondered if not wearing the safety belt had saved him or hurt him.
- There is a perception that if a truck rolls to the right, a safety belt will help. If it goes to the left, the safety belt could cause injury.

4.2.2. Topic 2: Safety Belts in CMVs versus Passenger Vehicles

Drivers stated that the air seats in a truck cab move up and down and front to back. The safety belt is usually fastened to the back of the cab and therefore causes rubbing against the neck. Unlike in a passenger vehicle, normal driving over rough roads and braking causes the safety belts to lock. Drivers also said that safety belts are hot to wear and become uncomfortable after they are worn all day.

4.2.3. Topic 3: When Safety Belts Are Used

Some of the nonusers wear safety belts some of the time. When asked, almost all say that they wear the safety belts when they go through weigh stations. Others buckle up in bad weather or heavy traffic. Some buckle up in their personal cars to be an example for their children.

4.2.4. Topic 4: Why Safety Belts Are Used

Some safety belt users said that they use safety belts only because it is the law. Others believed in the safety effects of safety belts. They also mentioned that it was simply a habit with them. The general feeling is that safety belts are worn to avoid traffic tickets, to avoid points on the CDL (which increases insurance costs), and to avoid company fees.

4.2.5. Topic 5: Safety Belt Comfort

Although some passenger vehicle drivers complain that safety belts are uncomfortable, the safety belts have improved. As the laws and enforcement have become stricter, safety belt use rates among passenger vehicle drivers have moved from 61 percent in 1996 to 81 percent in 2006. The overall rate for CMV drivers was 59 percent in 2006. One question is whether safety belts in CMVs are uncomfortable and whether this is the defining reason for nonusage of safety belts by CMV drivers.

Nonusers of safety belts complained about comfort, although personal freedom was also mentioned.

Observations and impressions on reasons the drivers dislike safety belts include the following.

Nonusers of Safety Belts

- Safety belts are uncomfortable for women and shorter people.
- It is hard to move around and there is a concern to be comfortable on a long haul.
- Safety belts are confining and restricting.
- Rubbing from bouncing is a factor in not wearing safety belts.
- The safety belts are too tight around the belly.
- Safety belts rub on the neck.
- Soreness results from wearing the safety belt.
- Personal freedom is violated.

Safety Belt Users

- In general, the safety belt users reported that the safety belts rub against their necks.
- When the Komfort Latch was used, it was pulled out to varying degrees. One person pulled it out just enough not to hit the steering wheel. One said that once he discovered the Komfort Latch, wearing a safety belt became much more comfortable.

4.2.6. Topic 6: Safety Belt Enforcement

Getting a ticket is a constant concern for most drivers. However, getting a safety belt violation is much less serious than getting a moving violation. Truckers reported trying to talk their way down to a safety belt violation, sometimes unbuckling the safety belt to give the officer the possibility. The safety belt enforcement was seen by many as a way for police agencies to make money. Users and nonusers felt that safety belt use was enforced and all of them knew to buckle up when they went through weigh stations. The general feeling among safety belt users is that if the penalty for getting a safety belt ticket were made as strict and as steep as that for getting a speeding ticket, people would start wearing safety belts.

4.2.7. Topic 7: Twelve Technologies to Increase Safety Belt Use

The 12 technologies considered in this study are presented next, along with representative statements or observations from drivers. Other suggestions and comments provided by the drivers are presented as well.

Technology 1. Safety Belt Tension Adjustor

Most of the drivers had the safety belt tension adjustor (or Komfort Latch) in their trucks. Not all of the drivers who had the Komfort Latch used it, although many did. Many drivers felt that the Komfort Latch made wearing the safety belt much more comfortable, and in some cases, drivers said they would not wear the safety belt without the Komfort Latch.

There was some confusion about the Komfort Latch’s effectiveness in a crash. Some believed that the Komfort Latch Device (plastic clip) was the only structure restraining the driver and that it would break during a crash. Some reported using the Komfort Latch to add a lot of slack to the safety belt, indicating that they sometimes add so much slack that their upper bodies would hit the steering wheel in the case of a crash. Some of these drivers were doing it to get around safety-belt-use laws; others did it for personal comfort.

Some felt that the Komfort Latch would not promote safety belt use. A small number felt that putting extra slack in the safety belt presented a hazard and that introduction of the Komfort Latch in more vehicles would not serve as an incentive for nonusers to begin using safety belts. Others were more positive and felt that if nonusers were instructed in the proper way to use the Komfort Latch, they might find them acceptable and feel more comfortable when wearing a safety belt.

The sliding Komfort Latch was not mentioned by the drivers. Many people mentioned the padded shoulder safety belt covers that protect a driver’s neck. They said the pads help, but were irritating over time. Some drivers indicated that they use a towel between the safety belt and their neck or chest for comfort.

Technology 2. Integrated Safety Belt

Drivers felt that a seat-integrated safety belt system seemed like a good idea to improve comfort. They understood that the shoulder strap upper anchorage point is integrated into the seat and they felt that this would be helpful in keeping the safety belt from rubbing against the neck. This was thought to be a good solution to the issue of the seat moving up and down, while the shoulder strap stays stationary, as in existing truck safety belts. Some drivers had integrated safety belts in their personal vehicles and felt that they worked well. One issue that the drivers immediately brought up was the concern that the seat would not be strong enough in case of a crash.

Technology 3. Four-Point Safety Belt

Four-point safety belts received strongly negative comments from most of the drivers. They were seen as potentially restrictive and hard to get out of in case of emergency. They were not seen as comfortable; however, none of the drivers had any personal experience with a four-point restraint system. In general, both the users and nonusers agree that the four-point safety belt does not seem viable.

Technology 4. Audible Reminders

The first response to the audible reminder was that drivers would find ways to disable them. Some felt that basic audible reminders that chime for a short period and shut off were not a strong intervention, but others said they might notice the chime and be reminded to buckle up. Regarding the enhanced system that chimes intermittently until drivers do buckle up, many felt the system would likely be effective in increasing belt use. Most drivers quickly understood how the system would work, since it exists in many passenger vehicles today. They felt that some drivers might attempt to disable the system, but many indicated that they would likely buckle up simply to stop the noise. They all agreed that it would be aggravating. Several suggested that some types of drivers making frequent stops (for deliveries or construction) should not be required to wear safety belts, or should not be required to have these systems in their trucks.

Technology 5. Dash Warning Light

In the discussion, the dash warning light was not reported by any as an effective way of increasing safety belt use. In addition, disabling or covering it up was seen as very easy. New large trucks are beginning to be equipped with this technology, although it is not a requirement. It is estimated that 30 percent to 50 percent of new Class 8 trucks are equipped with passive dash warning light systems (see Table 3 for estimates in other vehicle classes).

Technology 6. Transmission Interlocks

Many of the safety belt users felt that the transmission interlock would certainly work, since drivers could not move their trucks unless they wore safety belts. However, they were unclear how the devices would be implemented. They strongly objected to having a technology that could require them to wear safety belts when maneuvering vehicles in parking areas or backing up the truck. Another strong concern is that the technology would malfunction, which could make them lose a day of work, or be late with a delivery, or leave them stranded.

Technology 7. Heating and Cooling System Interlocks

The concern with this idea was primarily that the heating and cooling system should work while the vehicle is parked, and that the driver would not be required to wear a safety belt at that time. Another concern is that it might break, especially during the cold winter months.

Technology 8. Entertainment System Interlock

The radio or CD players were not considered as important as the CB radio. Some said that their entertainment system was not important to them. Again, most said that this should not impair their ability to use the CB radio when the truck was not moving and when they did not need to wear safety belts. This technology did not generate a lot of discussion.

Technology 9. Onboard Data Recorders

OBDRs met with a generally negative response from the drivers, particularly from the nonusers of safety belts. The potential to circumvent the system was discussed at length. The question of who would collect the onboard data for owner-operators was considered. The assumption is that DOT would collect it. There was a lot of suspicion that the onboard data collectors would be used to collect many other different types of data that would be used against the driver.

Technology 10. Exterior Safety-Belt-Use Indicator Light

The new concept of an exterior safety-belt-use indicator light was met with a great deal of resistance. Drivers felt that this type of device would be unfair treatment since passenger vehicles had no such requirement. They also felt that enforcement officials (primarily police) would not want to spend valuable time pulling over drivers in violation of safety belt use laws and that they would use the safety-belt-use indicator light to stop vehicles to find other issues to cite. Later in the project, someone suggested that the light be affixed to the truck cab, not the trailer. The exterior safety-belt-use light was seen as technically challenging and expensive to implement because the cab and the load had different electrical systems.

Technology 11. Brightly Colored Safety Belts

This was one of the selections most favored by the safety belt users. They felt that the increased enforcement brought about through brightly colored safety belts would encourage nonusers to wear safety belts. One driver stated that safety belts in all CMVs would need to be changed to a bright color at the same time to make law enforcement consistent.

The nonusers were much less enthusiastic about brightly colored safety belts and suggested ways to get around the safety belt. There are already shirts on the market that have a safety belt printed across the front, giving the impression that the driver is buckled. Drivers suggested wearing shirts the same color as the safety belt.

Another driver suggested that the safety belts have a heat strip on the back. This would indicate to the police office whether it had been on the driver or whether the driver had just buckled up upon being pulled over. Another driver suggested that they just spray paint all the safety belts a bright color.

Technology 12. Weigh Station Transponder

The weigh station transponder is seen as a variation on cameras at the weigh stations, which already do the same job. Some envisioned the transponder as working like the prepass. They felt that this would be effective since truck drivers would buckle up to be able to use the prepass and avoid direct contact with the DOT inspectors. Some thought, however, that the safety belts could be removed as soon as they passed through the station.

4.2.8. CMV Driver Discussion Summary

The driver discussions highlighted many concerns and opinions regarding the use and effectiveness of safety belts and the proposed technologies. They showed a broad range of perspectives on most topics, while occasionally showing agreement among safety belt users and nonusers. Overall, safety belt users and nonusers favored brightly colored safety belts and safety belt tension adjustors. Nonusers felt that enhanced audible reminders would be obtrusive, which suggests that they would be effective in compelling drivers to buckle up. Safety belt users acknowledged that they would likely not be affected by reminder systems and indicated that this would be an acceptable and practical solution. The possible impact of seat-integrated safety restraints was not well understood; however, drivers did recognize the potential for reduced rubbing and irritation with seat-integrated safety restraints compared to traditional safety belts affixed to the vehicle B-pillar.

During the discussion, drivers suggested that education regarding the effectiveness of safety belts and the correct use of technologies would help to dispel common myths about the “dangers” of wearing a safety belt. Many agreed that education and the threat of monetary penalties or rewards are the best ways to encourage safety belt use.

5. BENEFIT-COST ANALYSIS

Below, a benefit cost analysis (BCA) is presented that compares the likely injury and fatality reductions due to increased safety belt use with the estimated cost of devices that are designed to promote the use of safety belts. Injuries and fatalities for drivers of all large trucks 10,001 pounds or more GVWR, specifically Class 7 and Class 8 drivers, are considered here. The resulting data allow for the evaluation of any safety belt technology option if a device cost is known and an estimate of device effectiveness in promoting safety belt use can be made. Within Chapter 6, these data are applied to estimate BCRs for the four most promising systems as indicated by industry stakeholders.

This chapter is divided into three sections describing: (1) the data sources and derivation of injury costs by safety belt use/non-use for Class 7 and 8 drivers, (2) device costs for technologies under consideration, and (3) a matrix of BCRs that can be applied to evaluate any of the devices under consideration.

In general, the analysis presented first involves the determination of injury costs for belted drivers and unbelted drivers. Since safety belts are not equally effective for all crash types (head-on, rollover, rear, etc.), it was necessary to calculate separate injury costs by safety belt use/non-use for each crash type. The difference between the actual annual cost of injury to belted and unbelted drivers of large trucks and the expected cost of injury if all drivers were now belted is the potential injury cost savings. The maximum injury benefit would be realized if a safety belt technology was 100 percent effective in increasing safety belt use (e.g., addressing the 41 percent of drivers not currently buckled). Since a 100 percent usage rate is not likely, the total potential cost savings is scaled based on the changes in usage rate anticipated for each device. Anticipated increases in safety belt use per device were estimated based on expert opinions provided by industry stakeholders.

For example, if a device compels 20 percent of the unbelted population to buckle up, it is expected that 20 percent of the potential injury cost reductions would be achieved. This value is then compared to the cost per proposed device, amortized over the anticipated lifespan of the device, times the number of vehicles in the fleet to be equipped. If the ratio of the injury benefit to the total fleet-wide cost is greater than 1, the device is considered cost-beneficial. Similarly, if the total injury benefit anticipated is less than the cost to install the device across the vehicle fleet, the device is not cost-beneficial.

5.1. INJURY COSTS

In this section, total injury costs for two populations were calculated. The first is the total cost of injury based on the current safety belt use rates. The second estimates injury costs if all drivers were belted. The difference between these two costs provides an overall estimate of the total potential opportunity for cost savings with increased safety belt use.

Modeling injury costs by safety belt use/non-use requires information regarding the number of belted and unbelted occupants involved in crashes, the medical details of each person’s injuries, and the costs of those injuries and associated travel delay. The 2001–2003 LTCCS data provide a sample of recent United States truck incidence data on crash injuries that record both safety belt use and medical descriptions of the injuries. To qualify for the LTCCS sample, a crash must have involved a large truck with at least one fatality ("K," "A," or "B" injury on the KABCOU scale, where K = killed, A = incapacitating injury, B = non-incapacitating injury, C = possible injury, O = no injury, and U = injury, severity unknown). The 2001–2003 LTCCS data were used in this study to estimate injury costs by safety belt use/non-use for these crashes, and the 1982–1986 National Automotive Sampling System (NASS) data were used for less severe crashes. However, using the LTCCS sample in the analysis for this report introduces selection bias since it is likely that some "C" or "O" crashes were left out of the sample because safety belts might have prevented injuries that could otherwise be severe enough to qualify for entering the sample.

To calculate the cost of injuries in the 2001–2003 LTCCS data, costs per victim in 2000 dollars were assigned by body part, whether or not a fracture was involved, and Abbreviated Injury Scale (AIS) score. These were updated to 2005 dollars and were merged onto the crash files, calculating the economic costs per victim. A more detailed description of the process used to assign per person costs is provided in Zaloshnja, et al. (2004). The costs per person are also applied for other transportation cost evaluations for FMCSA, NHTSA, and the Federal Highway Administration (FHWA). Economic costs represent the present value of all injury-related costs that result from a crash over the victim's expected lifespan, computed at a 4 percent discount rate. This discount rate was chosen in order to be consistent with NHTSA's and FHWA's methodology. Included were the following major categories of costs: (1) medically related, (2) emergency services, and (3) lost productivity (wage and household work). These items, when summed, are the economic cost of injury. Comprehensive costs include items 1–3 plus the monetized value of pain, suffering, and lost quality of life. For this study, economic costs were used because this cost is most likely absorbed by employers in the event of a crash.

A number of data sources were used to determine injury costs. Medical cost estimates were drawn from 1992–1994 Civilian Health and Medical Program of the Uniformed Services (CHAMPUS) data for physician and emergency department fees, 1994–1995 data on hospital costs from Maryland and New York (the only two states where costs, not charges or payments, were known), and the 1987 National Medical Expenditure Survey (NMES) and 1979–1987 National Council on Compensation Insurance (NCCI) data on the percentage of costs that occur more than six months post-injury. Short-term productivity loss is based on information from the NASS Crashworthiness Data System (CDS) 1988–1991 (for AIS 85) and CDS 1993–1999 (for AIS 90) to determine the probability that an employed person would not be able to work due to a specific injury. Further, the 1993 Survey of Occupational Injury and Illness (SOII) of the U.S. Bureau of Labor Statistics was used to estimate the days of work lost per person due to injury. Mean probabilities of work loss were estimated from just those CDS records that had the relevant information, which frequently was missing. Long-term productivity loss by diagnosis was based on 1979–1987 NCCI Detailed Claims Information (DCI) data on the probability that injuries would cause permanent partial/total disability and 1997 DCI data on the percentage loss of earning power for partially disabled injury victims.

Various other direct costs were also determined, including emergency services costs, travel delay, insurance claims administration, legal and court costs, and workplace disruption costs. These estimates used insurance data, recent data on travel delay that crashes caused to motorists whose vehicles did not crash, and data from prior NHTSA studies.

The effect of varied safety belt effectiveness by crash type must be accounted for when calculating injury costs. Mean costs were calculated while controlling rollover, rear-end, head-on, angle, sideswipe, and other frontal collisions. The analysis of K, A, and B crashes from the LTCCS indicated that differences in mean injury costs between belted and unbelted truck drivers were statistically significant at the 95 percent confidence level for all crash types, with the exception of sideswipe crashes and rear crashes in which the large truck was the vehicle struck. This result is logical, since safety belts are most effective in preventing occupant contact with interior components and occupant ejections.

The data shown in Table 5 indicate that if all unbelted drivers of large trucks (GVWR 10,001 pounds or more) had been belted at the time of their crashes, the annual economic injury costs would have been $675 million lower than those observed ($2,253 million [column 6] minus $1,578 million [column 7]). Most of these savings would have come from injury cost reduction during rollovers ($434 million), followed by injury cost reductions during head-on collisions and other frontal collisions ($120 million).

The data shown in Table 5 indicate that if all Class 7 and 8 truck drivers were belted at the time of their crashes, the annual economic injury costs would have been $489 million lower than those observed ($1,903 million [column 6] minus $1,414 million [column 7]). Most of these savings would have come from injury cost reduction during rollovers ($369 million), followed by head-on collisions and other frontal collisions ($134 million). At this time however, it is clear that no device exists that is capable of increasing safety belt use to 100 percent. The estimate allows for the direct calculation of likely cost reduction if the device effectiveness is known or can be estimated. These cost estimates are applied in Chapter 6 to estimate cost-benefit ratios, assuming an estimated effectiveness for each of the safety belt technologies considered here. The chapter applies estimated effectiveness values in order to estimate injury cost reductions likely with the implementation of each device.

Table 4. Annual Injury Cost Savings If Drivers in All Large Truck Crashes Were Belted

Crash Type	Safety Belt Use	Observations (LTCCS)	Annual Frequency	Mean Economic Injury Cost	Annual Economic Injury Cost (in 2005 $ millions)	Annual Economic Injury Cost If All Unbelted Drivers Were Belted (in 2005 $ millions)	Annual Economic Injury Cost Savings If All Unbelted Drivers Were Belted (in 2005 $ millions)
Rollover	Unbelted	83	5,479	$145,384	$797	$363	$434
Rollover	Belted	125	7,332	$66,125	$485	$485	$0
Rear-end	Unbelted	46	1,941	$14,048	$27	$49	$-22
Rear-end	Belted	210	9,118	$25,308	$231	$231	$0
Head-on	Unbelted	9	468	$276,781	$130	$9	$121
Head-on	Belted	35	1,770	$19,600	$35	$35	$0
Angle	Unbelted	39	1,533	$45,360	$70	$16	$54
Angle	Belted	231	10,133	$10,522	$107	$107	$0
Sideswipe	Unbelted	12	631	$3,934	$2	$2	$0
Sideswipe	Belted	38	2,061	$3,020	$6	$6	$0
Other	Unbelted	30	1,173	$148,986	$175	$86	$88
Other	Belted	60	2,582	$73,709	$190	$190	$0
Drivers of All Large Trucks	Unbelted	219	11,224	$106,919	$1,200	$525	$675
Drivers of All Large Trucks	Belted	699	32,996	$31,926	$1,053	$1,053	$0
Total		**918**	**44,220**	**$50,961**	**$2,253**	**$1,578**	**$675**

Source: LTCCS 2001–2003 data. Note: Economic injury cost excludes monetized value of pain, suffering, and lost quality of life.

Table 5. Annual Economic Injury Cost Savings If All Class 7 and 8 Truck Drivers in Crashes Were Belted

Crash Type	Safety Belt Use	Observations (LTCCS)	Annual Frequency	Mean Economic Injury Cost	Annual Economic Injury Cost (in 2005 $ millions)	Annual Economic Injury Cost If All Unbelted Drivers Were Belted (in 2005 $ millions)	Annual Economic Injury Cost Savings If All Unbelted Drivers Were Belted (in 2005 $ millions)
Rollover	Unbelted	73	4,870	$142,450	$694	$325	$369
Rollover	Belted	112	6,639	$66,596	$442	$442	$0
Rear-end	Unbelted	41	1,802	$14,293	$26	$40	$-14
Rear-end	Belted	193	8,597	$22,017	$189	$189	$0
Head-on	Unbelted	7	374	$149,555	$56	$7	$49
Head-on	Belted	33	1,769	$19,431	$34	$34	$0
Angle	Unbelted	31	1,154	$10,800	$12	$12	$0
Angle	Belted	213	9,543	$10,326	$99	$99	$0
Sideswipe	Unbelted	10	590	$4,042	$2	$2	$0
Sideswipe	Belted	33	1,880	$2,862	$5	$5	$0
Other	Unbelted	28	1,036	$158,802	$165	$80	$85
Other	Belted	49	2,314	$77,080	$178	$178	$0
Drivers of All Large Trucks	Unbelted	190	9,827	$97,165	$955	$466	$489
Drivers of All Large Trucks	Belted	633	30,741	$30,840	$948	$948	$0
Total		**823**	**40,568**	**$46,906**	**$1,903**	**$1,414**	**$489**

Source: LTCCS 2001–2003 data. Note: Economic injury cost excludes monetized value of pain, suffering, and lost quality of life

5.2. DEVICE COSTS

Cost estimates applied during this analysis included both aftermarket device costs and installation costs when possible, or original equipment estimated costs. The original equipment costs do not account for device development costs, re-engineering of devices, or testing required for certifying the systems. This allows for the objective comparison of costs for multiple systems without the need to request proprietary development and engineering costs from device suppliers and OEMs.

It should be mentioned that few devices described in Chapter 3 are available as original equipment or as aftermarket products. The cost to a buyer to incorporate certain features would be drastically lower if the equipment were installed by the manufacturer when the vehicle is first assembled. As an example, if a vehicle were equipped with a brightly colored safety belt at the manufacturers, the incremental cost of installing the safety belt system, which is only $12 more to purchase, is far less significant. This minimal cost increase is likely due to the difference in production volumes for black versus brightly colored safety belts. However, if brightly colored safety belts are purchased as an aftermarket product, the current standard industry practice is to replace the complete safety belt system, including the safety belt webbing, buckle and stalk, D-ring, and retractor. This information was provided by certified repair shops and aftermarket device manufacturers. Cost estimates for complete system replacements vary by vehicle; however, estimates range from $95–$120 for baseline systems with brightly colored webbing. In addition, labor costs are approximately $90 for a complete replacement safety belt system.

Another important factor to consider, which is unique to CMV safety belts, is the replacement of subcomponents. Based on information supplied by certified repair shops and restraint manufacturers, it is not possible to replace individual components of a safety belt system. Because of potentially unsafe incompatibilities between parts, it is not possible to replace the safety belt webbing, latch plate, buckle, and buckle stalk, D-ring, or retractor mechanism separately. Rather, the replacement of one component requires replacement of the entire system. This condition significantly increases the total cost that would be expected to retrofit the entire vehicle fleet with upgraded or slightly varied components.

In Chapter 3, a description of 13 safety belt technologies that could impact safety belt use was presented. From that list, four of the most promising systems (enhanced audible reminders, brightly colored safety belts, seat-integrated safety restraints, and safety belt tension adjustors) were selected based on stakeholder feedback. The process of estimating aftermarket costs for these devices was not straightforward. Table 6 lists aftermarket costs plus labor costs, in addition to original equipment costs, for some of the technologies.

Table 6. Estimated Safety Belt Device Costs

Technology	Estimated Device Plus Installation Cost
Safe Driving Sticker (sticker plus 1 year of service)	$15
Brightly Colored Safety Belt System (aftermarket cost including labor)	$197
Brightly Colored Safety Belt System (original equipment, manufacturer's cost)	$107
Safety Belt System plus Adjustable D-ring (original equipment, manufacturer's cost)	$115
Safety Belt System plus Komfort Latch Device (original equipment, manufacturer's cost)	$125
Safety Belt System plus Buckle Sensor and Active Visual Reminder (original equipment, manufacturer's cost)	$170
Safety Belt System plus Buckle Sensor Enhanced Audible Reminder (original equipment, manufacturer's cost)	$170
Seat-Integrated Safety Restraint System (original equipment, manufacturer's cost)	$700
Electronic Onboard Data Recorder (basic system: original equipment, manufacturer's cost)	$2,500

As mentioned previously, only one configuration is available for a safety belt system for a particular make, model, and model year vehicle. For example, it is not possible to order a safety belt system with an optional Komfort Latch device or an optional height adjustor. For this reason, it was difficult to discriminate the incremental cost for certain components like the Komfort Latch and D-ring height adjustors. In order to determine an average price for the baseline safety belt system, a system with an adjustable D-ring and a system with a Komfort Latch device, the research team identified three vehicles with each configuration and contacted parts suppliers to determine replacement costs per device. The costs are listed in Table 6. As shown in the table, the per-vehicle cost for the safe driving sticker ($15 including 1 year of service by a monitoring company) is the least expensive option considered. Original equipment for brightly colored belts (total cost $107 = $95 for basic belt system + $12 for upgraded webbing) is the second least expensive device.

The brightly colored safety belt system and the active visual reminder systems are available as optional upgrades from the manufacturer, so that device costs shown are calculated by adding the incremental cost increase quoted by manufacturers to the baseline average device cost.

Since equipping a vehicle with a technology like those shown in Table 6 results in a one-time cost increase during vehicle purchase, the cost was evenly distributed, or the cost of the device was amortized, over the expected lifetime of the vehicle. This allowed comparison of the annual cost of the device with the anticipated annual injury savings. The estimated lifespan of large trucks in primary use is 12 years. Many vehicles are kept in service beyond 12 years, but their use is infrequent and not considered primary. This amortized device cost is then multiplied by the number of vehicles registered in 2005 (FHWA, 2005), resulting in an estimate of the annual device cost to equip the full fleet. Based on 2005 data, there were 8,481,999 large trucks registered and 2,328,205 of those were Class 7 and 8 vehicles.

Each device cost is amortized over 12 years (lifespan of the device) at a 4 percent discount. The figure of 4 percent was chosen to be consistent with the 4 percent used to discount crash costs.

5.3 BENEFIT-COST RATIOS

BCRs are calculated by dividing the annual expected injury benefit in dollars by the annual cost of the devices. If the ratio is greater than 1, the device can be thought of as cost-beneficial, or providing a positive return on investment. The investment would be the purchase of the safety device by an individual or fleet owner, and the return would be a reduction in the cost of injury sustained by drivers and likely paid for by fleet owners directly or through insurance or other means.

As an example, Table 7 lists device costs where the anticipated cost of devices equals the anticipated savings due to injury reduction. These costs are the maximum amount that could be spent on a device before a negative return on an investment in a safety device would occur. With regard to Table 7, even if only a 5 percent increase in safety belt use were realized through the addition of a particular device, it would prove to be cost-beneficial if it costs less than $91 for all trucks and less than $240 for Class 7 and 8 trucks. Similarly, if a device increases safety belt use by 30 percent, any device costing less than $545 for all trucks and $1,440 for Class 7 and 8 trucks would prove to be cost-beneficial when fatality and injury reductions are considered.

Table 7. Maximum Device Cost versus Anticipated Effectiveness

Anticipated Increase in Safety Belt Use	Maximum Cost Effectiveness per Vehicle for All Large Trucks	Maximum Cost Effectiveness per Vehicle for Class 7 and 8 Vehicles
5%	$91	$240
10%	$182	$480
15%	$273	$725
20%	$364	$960
25%	$454	$1,200
30%	$545	$1,440
35%	$635	$1,680
40%	$730	$1,920

[1] A device that is expected to increase safety belt use by 5 percent would improve wearing rates from 59 percent (2006 estimate) to 64 percent if fully deployed.

In order to determine an exact BCR, exact device costs and exact effectiveness values are required. In this case, neither value is known with certainty for the most promising safety belt technologies described previously. For this reason, Table 8 provides a matrix of BCRs for the population of drivers of all large trucks. (Table 9 provides similar information for Class 7 and 8 drivers only.) Each cell represents the ratio of a single device cost at a given effectiveness. As an example, if a device that leads to a 10 percent increase in overall safety belt use by Class 7 and 8 drivers is purchased at a price of $80, the BCR value of 4 indicates that for every dollar spent to purchase and equip trucks with the device, a $4 return is expected for companies. Similarly, if $1 million is spent, a $4 million return in injury cost savings is anticipated.

The matrix of BCRs shown in Tables 8 and 9 is presented so that the BCRs for other devices not explicitly discussed in this document can be determined.

Table 8. Generalized Benefit-Cost Ratios for Safety Belt Technologies for Drivers of All Large Trucks—Anticipated Increase in Safety Belt Use (from 59% baseline)

Device Cost	5%	10%	15%	20%	25%	30%	35%	40%
$10	9.11	18.22	27.33	36.43	45.54	54.65	63.76	72.87
$20	4.55	9.11	13.66	18.22	22.77	27.33	31.88	36.43
$30	3.04	6.07	9.11	12.14	15.18	18.22	21.25	24.29
$40	2.28	4.55	6.83	9.11	11.39	13.66	15.94	18.22
$50	1.82	3.64	5.47	7.29	9.11	10.93	12.75	14.57
$60	1.52	3.04	4.55	6.07	7.59	9.11	10.63	12.14
$70	1.30	2.60	3.90	5.20	6.51	7.81	9.11	10.41
$80	1.14	2.28	3.42	4.55	5.69	6.83	7.97	9.11
$90	1.01	2.02	3.04	4.05	5.06	6.07	7.08	8.10
$100	0.91	1.82	2.73	3.64	4.55	5.47	6.38	7.29
$200	0.46	0.91	1.37	1.82	2.28	2.73	3.19	3.64
$300	0.30	0.61	0.91	1.21	1.52	1.82	2.13	2.43
$400	0.23	0.46	0.68	0.91	1.14	1.37	1.59	1.82
$500	0.18	0.36	0.55	0.73	0.91	1.09	1.28	1.46
$600	0.15	0.30	0.46	0.61	0.76	0.91	1.06	1.21
$700	0.13	0.26	0.39	0.52	0.65	0.78	0.91	1.04
$800	0.11	0.23	0.34	0.46	0.57	0.68	0.80	0.91
$900	0.10	0.20	0.30	0.40	0.51	0.61	0.71	0.81
$1,000	0.09	0.18	0.27	0.36	0.46	0.55	0.64	0.73
$2,000	0.05	0.09	0.14	0.18	0.23	0.27	0.32	0.36
$3,000	0.03	0.06	0.09	0.12	0.15	0.18	0.21	0.24

Table 9. Generalized Benefit-Cost Ratios for Safety Belt Technologies for Class 7 and 8 Drivers—Anticipated Increase in Safety Belt Use (from 59% baseline)

Device Cost	5%	10%	15%	20%	25%	30%	35%	40%
$10	24.09	48.18	72.27	96.36	120.45	144.54	168.63	192.72
$20	12.05	24.09	36.14	48.18	60.23	72.27	84.32	96.36
$30	8.03	16.06	24.09	32.12	40.15	48.18	56.21	64.24
$40	6.02	12.05	18.07	24.09	30.11	36.14	42.16	48.18
$50	4.82	9.64	14.45	19.27	24.09	28.91	33.73	38.54
$60	4.02	8.03	12.05	16.06	20.08	24.09	28.11	32.12
$70	3.44	6.88	10.32	13.77	17.21	20.65	24.09	27.53
$80	3.01	6.02	9.03	12.05	15.06	18.07	21.08	24.09
$90	2.68	5.35	8.03	10.71	13.38	16.06	18.74	21.41
$100	2.41	4.82	7.23	9.64	12.05	14.45	16.86	19.27
$200	1.20	2.41	3.61	4.82	6.02	7.23	8.43	9.64
$300	0.80	1.61	2.41	3.21	4.02	4.82	5.62	6.42
$400	0.60	1.20	1.81	2.41	3.01	3.61	4.22	4.82
$500	0.48	0.96	1.45	1.93	2.41	2.89	3.37	3.85
$600	0.40	0.80	1.20	1.61	2.01	2.41	2.81	3.21
$700	0.34	0.69	1.03	1.38	1.72	2.06	2.41	2.75
$800	0.30	0.60	0.90	1.20	1.51	1.81	2.11	2.41
$900	0.27	0.54	0.80	1.07	1.34	1.61	1.87	2.14
$1,000	0.24	0.48	0.72	0.96	1.20	1.45	1.69	1.93
$2,000	0.09	0.19	0.28	0.37	0.47	0.56	0.65	0.75
$3,000	0.06	0.12	0.19	0.25	0.31	0.37	0.43	0.50

CHAPTER 6. TECHNOLOGY SUMMARY

In this chapter, a synthesis is presented of all available information regarding the four safety belt technology strategies considered the most promising. The method used to select the most promising systems included both subjective and objective criteria. The decision was based on the feedback of industry stakeholders regarding the most reasonable, potentially effective, and cost-effective systems. In addition, user acceptability was obtained through driver discussions and resulting feedback. The following four technologies were selected as the most promising:

- Enhanced Audible Reminders
- Brightly Colored Safety Belts
- Safety Belt Tension Adjustors
- Seat-Integrated Safety Restraints

Data gathered during the literature review, industry stakeholder discussions, and driver discussions are presented in the following sections. Final BCRs are presented for the population of all large trucks by device and also for the population of Class 7 and 8 trucks per device. Based on 2005 data reported by FHWA, there were 8,481,999 large trucks registered (GVWR 10,001 pounds or more) and 2,328,205 of these were Class 7 and 8 vehicles. Device effectiveness in increasing safety belt use is estimated based on expert opinions provided by industry stakeholders. These effectiveness values are estimates and were necessary for the purpose of calculating BCRs; however, observational studies of actual changes in belt use with the implementation of each device should be conducted to confirm these values.

The methodology used to estimate BCRs was presented in Chapter 5. The matrix of values listed in Tables 8 and 9 allows the reader to determine the BCR for any promising system likely to increase driver belt use, if the device cost and potential effectiveness of each system are known.

6.1. ENHANCED AUDIBLE REMINDERS

The enhanced audible reminder system seemed to appeal most to stakeholders. This device, available as a standard feature in over 75 percent of new passenger vehicles sold in 2006, provides a repeating audible alert to drivers until safety belts are properly engaged (Alliance of Automobile Manufacturers, 2006). One implementation of this system in passenger cars provides an 8-second alert every 20 seconds for up to 5 minutes until safety belts are fastened (Williams, 2003). After a period of 5 minutes, these systems stop issuing the audible reminder. Other implementation strategies have also been used in which the intensity of the audible chime, frequency of alerts, time duration, and the alert's sound are varied (Saab, 2005). Within the scientific literature, little information is available describing specific implementation strategies for large trucks. Useful guidelines do exist for passenger car drivers that could aid in the development of future systems if enhanced audible reminders were considered for implementation in large trucks (Eby, et al., 2005).

The Transportation Research Board (TRB) Special Report 278 study (Howell, et al., 2003) considered technologies to increase safety belt use in passenger vehicles and concluded that enhanced audible reminders would be effective in increasing safety belt use rates while not being overly obtrusive. The European vehicle rating system (EuroNCAP) assigns bonus points when rating vehicles if an enhanced audible reminder system is present.

6.1.1. Stakeholder Perspectives

The enhanced audible reminder was the device most widely accepted and supported by vehicle OEMs, government personnel, and industry trade organizations. Numerous stakeholders supported this technology, indicating that the approach has been widely successful for passenger vehicles and would likely be successful for large-truck applications as well. The manufacturers indicated that the components necessary to implement an enhanced audible reminder system are readily available and would require minimal engineering effort to implement as an original equipment strategy. Stakeholders warned that care must be taken to properly integrate systems into the large-truck environment, which differs in many ways from the passenger vehicle fleet. For example, devices should account for the fact that drivers may need to be unbelted to perform low-speed driving tasks while parking or during other work-related activities.

Drivers felt that the device would be effective. A small number of nonusers indicated that the device would be sufficiently annoying that they would attempt to disable the system. Many part-time drivers felt that they would benefit from the reminder, and they would appreciate being able to temporarily or permanently disable the system if needed. The population of safety belt users identified that the chime would have little impact on them. They anticipated that they would never hear the reminder because they typically operate their vehicles only when their safety belts are fastened. All drivers (users and nonusers) felt that the devices would increase safety belt use by drivers in their industry.

6.1.2. Anticipated Device Effectiveness

Effectiveness data for enhanced audible reminder systems exist for passenger vehicle applications only. The data are based on direct observation of passenger-vehicle-driver safety belt use and were reported by Williams, et al. (2003). The study reports that a 7 percent higher safety belt use rate was observed for passenger vehicle drivers whose vehicles were equipped with the system, compared to drivers of vehicles not equipped with the technology. This incremental difference provides one estimate of the potential effectiveness of an audible reminder system in large trucks. However, the Ford system allows users to temporarily or permanently disable the device. Without this option, stakeholders anticipate that an enhanced audible reminder system would increase safety belt use by CMV drivers by 15 percent. In the absence of all other data regarding potential device effectiveness, these data were applied to calculate the BCR ratios shown next.

1. Estimated aftermarket cost: Enhanced audible reminders are not available as aftermarket systems.

2. Estimated original equipment cost: $105

$70—Buckle with safety belt use sensor switches plus wiring to onboard computer

$35—Enhancement for onboard computer and interface with existing chime

3. Anticipated BCR: N/A—Aftermarket

2.6—Original equipment for all large trucks
6.9—Original equipment for Class 7 and 8 trucks

As previously mentioned, a BCR above 1 indicates a positive return on an investment where each dollar spent would likely result in more dollars saved by prevention of injuries and fatalities than the devices cost. Conversely, a BCR below 1 indicates that the device is not cost-beneficial and there would be a negative return on investment.

6.2. BRIGHTLY COLORED SAFETY BELTS

Brightly colored safety belt systems are an enforcement strategy in which the bright colors permit company officials, DOT inspectors, and law enforcement personnel to more easily identify if safety belts are being worn. In addition, the bright color (usually orange or yellow) makes safety belt systems more noticeable to drivers and this, too, might serve as a reminder to buckle up. This strategy is currently being introduced by fleets of all sizes in order to facilitate enforcement of safety-belt-use policies and to encourage drivers to buckle up. Few technical data exist regarding this particular device; however, multiple studies have suggested that enforcement and the perceived threat of enforcement lead to significant increases in safety belt use.

6.2.1. Stakeholder Perspectives

Stakeholders identified brightly colored safety belts as the second most favored strategy for increasing safety belt use. Trade organization representatives and insurance personnel identified that the introduction of these safety belts to a vehicle indicates to drivers that a company cares about the well-being of its drivers. They also felt that introducing the safety belts to fleet vehicles provides an opportunity for a company to revisit the issue of safety belt use and provide additional safety education to drivers. Devices are cost-effective, especially when included in the purchase of a new vehicle. Two fleet safety managers who have already implemented brightly colored safety belts in their fleets indicated that these devices have made noticeable differences in their drivers' behavior. Some have suggested that the success of brightly colored safety belts relies on the fact that someone is looking for the safety belts (either police or company personnel); however, it appeared to fleet managers that the fear of enforcement by police was sufficient to increase safety belt use rates.

6.2.2. Anticipated Device Effectiveness

Few data are currently available to assess the likely impact of brightly colored safety belts. The calculation below assumes an estimated safety belt use increase of 10 percent with the implementation of brightly colored belts. This estimate is based on stakeholder feedback and researcher opinion regarding the likely effectiveness of this system. Additional studies are necessary to determine actual effectiveness values based on observed belt use in the field.

1. Estimated aftermarket cost: $197

$95—Baseline belt system cost

$90—Labor

$12—Incremental cost for changed webbing (due to lower production volumes)

2. Total estimated original equipment system cost: $107

$95—Baseline belt system cost

$12—Incremental cost for changed webbing (due to lower production volumes)

3. Anticipated BCR

0.92—Aftermarket for all large trucks

2.45—Aftermarket for Class 7 and 8 trucks

1.70—Original equipment for all large trucks

4.50—Original equipment for Class 7 and 8 trucks

6.3. SAFETY BELT TENSION ADJUSTORS

Safety belt tension adjustors are devices that allow users to introduce slack into safety belts to improve the overall comfort of safety belts in trucks. Since large trucks often have suspended seats that travel vertically and horizontally while the truck is in motion, the relative movement between safety belt systems fixed to vehicle interiors and drivers using suspended seats may lead to excessive rubbing and irritation of the shoulder and chest of drivers. Currently, safety belt tension adjustors (sold commercially as Komfort Latch) are sold in nearly 90 percent of new Class 8 vehicles. This estimate was provided by the manufacturer of the Komfort Latch System.

The device is an integrated component that attaches to the vehicle structure at the D-ring. The device can be cinched to hold the safety belt in place after introducing slack into the safety belt system. In making the shoulder portion of the safety belt fit less tightly, the rubbing of the safety belt across the neck of an occupant is minimized. The system can be disengaged by yanking on the system; it will disengage automatically during a collision event, once extended beyond the locked level. The system does not affect the activation of web-lockers or load limiters that are part of the safety belt system.

Some questions have been raised regarding the introduction of additional slack into the safety belt system. A study by Siegmund, et al. identified a 26 percent to 37 percent increase in head, thoracic, and pelvic accelerations and a 20 percent to 54 percent increase in neck loads and moments with the addition of 10 centimeters of slack. As reported during manufacturer discussions, most commercial vehicles do not come equipped with pretensioning retractors that rapidly remove slack from a safety belt system in the event of a crash. This is especially true for Class 6 and larger vehicles. Ideally, a safety belt system should closely couple an occupant to the decelerating vehicle structure as early as possible during a crash event. If additional slack exists in the system, the safety belt does not decelerate an occupant for as long a period of time before the vehicle structure comes to rest. In this case, an occupant will experience a higher deceleration force over a shorter period of time before he or she is brought from precrash speeds to rest during a crash. Additional quantification of the safety effects of added slack would be useful in supporting this device.

6.3.1. Stakeholder Perspectives

Multiple manufacturers indicated that some vehicles lines are equipped with the safety belt tension adjustor (i.e., Komfort Latch System). Although OEMs felt that adding slack to a safety belt was not ideal and could lead to reduced safety belt effectiveness in preventing injuries in some cases, if this comfort strategy increased safety belt use, some stakeholders suggested the tradeoff might be acceptable. A number of drivers reported that they used the safety belt tension adjustor regularly and would be less likely to buckle up if their vehicles were not equipped with the device. Other drivers indicated that they preferred the baseline safety belt system and did not find comfort to be an issue.

6.3.2. Anticipated Device Effectiveness

Safety belt tension adjustors are available today in a large proportion of Class 7 and Class 8 vehicles. In some cases, regular safety belt users prefer not to add any slack to their safety belts while driving, even if a Komfort Latch is present. However, it appears there were other cases of vehicles being equipped with a Komfort Latch, but it was not used because its function was not well understood. This opinion is based on driver discussions.

Overall, the Komfort Latch could be useful in helping drivers to optimize the comfort of the safety belt when they choose to wear it. However, additional education regarding the benefit of wearing safety belts and ways to optimize a good fit with a Komfort Latch is essential. For the purpose of this evaluation, they were estimated to increase safety belt use by 5 percent.

1. Estimated aftermarket cost: This device is not available as an aftermarket system.

2. Total estimated original equipment system cost: $125

$95—Baseline safety belt system cost
$30—Incremental cost for Komfort Latch device

3. Anticipated BCR

N/A—Aftermarket
0.73—Original equipment for all trucks
1.93—Original equipment for Class 7 and 8 trucks

6.4. SEAT-INTEGRATED SAFETY RESTRAINTS

Seat-integrated safety restraints are a technology that could improve the comfort of safety belts without introducing slack into the system. These devices would be mounted directly to air- or spring-suspended seats. This eliminates the relative motion between the driver and the safety belt system. The safety belts are typically attached to fixed parts of the vehicle interior. This difference could address some driver comfort issues. However, attaching the safety belt system to the seat structure would increase the load transferred to the seat and mounting structure in the event of a crash. Currently, vehicles are not designed to withstand increased load on the seat. European designers are introducing seat-integrated safety restraints into their new vehicles. A number of studies conducted by European and Australian researchers have identified that seat-integrated safety restraints are a more comfortable alternative to traditional safety belts.

A seat-integrated safety belt system may also provide improved occupant protection during a crash. Since anchorage points (upper anchorage and lower attachment point) for the seat-integrated restraint system are closer to the driver, the degree of upper body restraint provided by the system during a crash may be significantly lower than that provided by a traditional system. This condition is primarily due to the larger distance between the driver seat and the vehicle B-pillar, and also due to the highly adjustable seats typically found in Class 7 and 8 vehicles. These closer attachment points lead to better coupling of the occupant to the seat in the event of a crash. Seat-integrated safety belts are not widely available in the United States; however, the technology shows much promise. These systems are more commonly available in Europe, Australia, and Japan.

6.4.1. Stakeholder Perspectives

Vehicle manufacturers (including vehicle structural engineers) indicated that design changes would be necessary for some vehicles to include seat-integrated safety restraints; however, engineering changes are not prohibitive. One aftermarket device manufacturer conducted preliminary evaluations of seat-integrated safety restraints and suggested that the upper anchorage location must be variable and further optimized before an acceptable solution can be implemented. A 10-percent increase in safety belt use is anticipated with the implementation of this device.

1. Estimated aftermarket cost: $970

Vehicle re-engineering not included here.

$700—Seat cost

$270—Labor

2. Total estimated original equipment system cost: $700

$700: Seat cost

3. Anticipated BCR

0.19—Aftermarket cost for all trucks

0.50—Aftermarket cost for Class 7 and 8 trucks

0.26—Original equipment for all trucks

0.69—Original equipment for Class 7 and 8 trucks

CHAPTER 7. CRASH DATA ANALYSIS

This chapter presents the results of an exploratory analysis of real-world data for fatal and nonfatal crashes involving large trucks. Data sources used for this analysis include the FARS database for fatal crashes and the Large Truck Crash Causation Study (LTCCS) to investigate truck crash causes and driver injury mechanisms in detail.

Analyses are designed to answer a number of questions and are organized in four sections:

1. What are the characteristics of fatal crashes involving large trucks, and are there any unique characteristics of fatal crashes common to unbelted drivers?
2. Under what conditions are belted drivers fatally injured?
3. What percentage of fatally and/or seriously injured unbelted drivers would have had improved outcomes if they had been wearing safety belts during their crashes?
4. What are the general characteristics and primary causes of large-truck rollover crashes?

To highlight unique characteristics of unbelted drivers, each result presented includes the population of belted drivers for comparison. Data are partitioned by truck type and presented separately for drivers of trucks whose GVWR is 10,001 pounds or more (referred to here as “All Large Trucks”) and for the population of Class 7 and 8 truck drivers (referred to here as “Class 7 and 8”). Within the data presented in this chapter, the population of Class 7 and 8 drivers is a subset of the total population of drivers of large trucks with a GVWR of 10,001 pounds or more.

7.1. CHARACTERISTICS OF FATALLY INJURED UNBELTED CMV DRIVERS

The FARS data were used to explore characteristics of large-truck driver-fatal crashes. The FARS is a census of police-reported fatal crashes occurring on public roadways in the United States where a death occurs within 30 days of the crash. The dataset includes environmental-, vehicle-, and occupant-level information for crashes involving large trucks, passenger vehicles, motorcycles, and pedestrians. All data elements are derived from police reports, hospital records, medical examiner/autopsy reports, and driver licensing information. All information presented is reported for the most recent available data year (2005), and in some cases, data from earlier years (1995–2005) are shown for comparison.

Overall, the FARS indicated that 5,212 people died in 2005 during crashes involving large trucks (those with a GVWR of 10,001 pounds or more). Of those fatalities, 688 were drivers of the large truck and 114 were large-truck passengers. For the subset of vehicles including Class 7 and 8 trucks, 602 drivers and 100 large-truck passengers died during 2005 calendar year crashes. The first goal of this analysis is to describe the characteristics of fatally injured unbelted drivers. Table 10 shows the number of belted and unbelted drivers of all large trucks who died during crashes occurring from 1995 to 2005. In addition, the table shows the population of fatally injured drivers whose safety belt use status could not be accurately determined after the crash. For the population of drivers fatally injured in 2005, some 337 were unbelted, which was 49 percent of the total fatally injured population. This percentage included drivers whose safety belt use status was unknown. It is likely that more than half of the driver fatalities where safety belt status was unknown were unbelted. Considering only fatalities in 2005 where safety belt use status was known for drivers of all large trucks (337 unbelted and 233 belted), 59 percent were unbelted, as shown in Table 10.

Table 10. Fatalities for Belted and Unbelted Drivers of All Large Trucks

Crash Year	Unbelted (% With Belt Use Known)	Belted (% With Belt Use Known)	Belt Use Unknown	Total All Large Trucks
1995	331 (74%)	116 (26%)	102	549
1996	324 (74%)	115 (26%)	94	533
1997	363 (72%)	141 (28%)	113	617
1998	329 (68%)	153 (32%)	141	623
1999	338 (66%)	175 (34%)	126	639
2000	366 (70%)	156 (30%)	123	645
2001	316 (68%)	152 (32%)	124	592
2002	302 (66%)	157 (34%)	120	579
2003	302 (61%)	196 (39%)	107	605
2004	299 (57%)	224 (43%)	102	625
2005	337 (59%)	233 (41%)	118	688

Source: FARS 1995–2005 data.

Table 11. Fatalities for Belted and Unbelted Drivers of Class 7 and 8 Trucks

Crash Year	Unbelted (% With Belt Use Known)	Belted (% With Belt Use Known)	Belt Use Unknown	Total Class 7 and 8
1995	285 (73%)	103 (27%)	96	484
1996	274 (71%)	110 (29%)	86	470
1997	299 (70%)	127 (30%)	104	530
1998	286 (69%)	130 (31%)	133	549
1999	302 (66%)	154 (34%)	116	572
2000	320 (69%)	143 (31%)	110	573
2001	278 (67%)	134 (33%)	118	530
2002	265 (66%)	137 (34%)	113	515
2003	269 (60%)	177 (40%)	104	550
2004	267 (57%)	201 (43%)	92	560
2005	281 (58%)	205 (42%)	116	602

Source: FARS 1995–2005 data.

Table 11 shows the fatality counts by crash year for belted and unbelted drivers of Class 7 and 8 trucks from 1995–2005. In 2005, some 281 out of 602 driver fatalities, or 47 percent, were unbelted. Considering only fatally injured drivers whose safety belt use status was known for drivers of Class 7 and 8 trucks (281 unbelted and 205 belted), 58 percent were unbelted in 2005, as shown in Table 11. It should be noted that the majority of the drivers of large trucks who died during the 1995–2005 crash years were drivers of Class 7 and 8 trucks (i.e.., 602 were Class 7 and Class 8 drivers versus 688 for all large trucks).

7.1.1. Crash Type Characteristics

Tables 12 and 13 show the distribution of driver fatalities by crash type (i.e., rollovers, vehicle-to-vehicle collisions, collisions with fixed and nonfixed objects, and noncollisions) in 2005 for all large-truck crashes and Class 7 and 8 truck crashes, respectively. These data are based on the most harmful event coded by FARS researchers. FARS defines the most harmful event as the event during a crash for a particular vehicle that is judged to have produced the greatest personal injury or property damage.

As shown in Table12, rollovers are the most common crash type in which a large-truck driver fatality occurs. Of the 688 fatalities, 232 (or 34 percent) of driver deaths occur during rollovers. Of these deaths, 66 percent involve an unbelted driver and 34 percent involve a belted driver. Vehicle-to-vehicle collisions include all crashes involving another moving vehicle. Of the 133 large-truck driver deaths occurring during vehicle-to-vehicle collisions, 46 percent involve unbelted occupants.

Collisions with fixed objects include narrow object crashes (impacts with trees and poles); crashes with walls, fences, and buildings; and crashes with fixed objects at the roadside, such as impact attenuators and guardrails. As shown in Table 12, some 63 percent of the 123 drivers fatally injured during collisions with fixed objects were unbelted. The “noncollision” category most commonly includes events in which a fire or explosion, a truck jackknife, or an occupant ejection without impact occurs. During these events, 48 percent of the fatally injured drivers were unbelted. The “collision with a nonfixed object” category includes impacts with parked vehicles, trains, and pedestrians/cyclists. Of the occupants involved in these crashes, 71 percent were unbelted.

Table 12. Distribution of Harmful Event Categories for CMV Driver Fatalities for All Large Trucks

Most Harmful Event	Safety Belt Use	Fatally Injured Drivers	Safety Belt Use per Event, When Known (%)	CMV Fatalities for All Large Trucks, Including Unknown (%)
Rollover (250)	Unbelted	152	66	36
Rollover (250)	Belted	80	34	
Rollover (250)	Unknown	18		
Vehicle-to-Vehicle (163)	Unbelted	61	46	24
Vehicle-to-Vehicle (163)	Belted	72	54	
Vehicle-to-Vehicle (163)	Unknown	30		
Collision with Fixed Object (139)	Unbelted	78	63	20
Collision with Fixed Object (139)	Belted	45	37	
Collision with Fixed Object (139)	Unknown	16		
Noncollision (99)	Unbelted	26	48	14
Noncollision (99)	Belted	28	52	
Noncollision (99)	Unknown	45		
Collision with Nonfixed Object (37)	Unbelted	20	71	5
Collision with Nonfixed Object (37)	Belted	8	29	
Collision with Nonfixed Object (37)	Unknown	9		
Total		**688**		**100**

Source: FARS 2005 data.

As suggested by Simon, et al. (2001), wearing a safety belt does not protect all occupants during all crashes. In crashes where a large amount of structural intrusion occurs, use of the safety belt system may not necessarily prevent serious injuries. However, in the absence of structural intrusion, the risk of fatal injury is quite low for properly restrained drivers. As shown in Table 12 and Table 13, safety belt use has a significant effect on the rate of fatality during rollovers and during collisions with fixed and nonfixed objects. Considering rollover crashes as an example, the percent of unbelted drivers who died is higher than the belted group (i.e., 66 percent unbelted versus 34 percent belted for large trucks), as shown in Table 12. This reflects the fact that many rollovers involving large trucks are not high-speed/multiple-roll events. In general, most large-truck rollovers involve only one quarter–turn, where the vehicle rolls only 90 degrees about its longitudinal axis. During these lower-severity rollover events, the vehicle structure and occupant compartment typically remain intact. During these events, it is possible that fatal injuries occur due to partial or full driver ejection, or due to movement of the driver within the vehicle compartment during the crash event. This outcome is further supported in section 7.2, “Characteristics of Fatally Injured and Belted CMV Drivers,” in which crash characteristics of belted drivers who were fatally injured are analyzed. This section highlights the fact that belted drivers are more often fatally injured in crashes where major structural damage results.

Table 13. Distribution of Harmful Event Categories for CMV Driver Fatalities in Class 7 and 8 Trucks

Most Harmful Event	Safety Belt Use	Fatally Injured Drivers	Safety Belt Use per Event, When Known (%)	CMV Fatalities for All Class 7 and 8, Including Unknown (%)
Rollover (223)	Unbelted	131	64	37
Rollover (223)	Belted	74	36	
Rollover (223)	Unknown	18		
Vehicle-to-Vehicle (132)	Unbelted	45	43	22
Vehicle	Belted	59	57	
Vehicle	Unknown	28		
Collision with Fixed Object (119)	Unbelted	65	63	20
Collision with Fixed Object (119)	Belted	38	37	
Collision with Fixed Object (119)	Unknown	16		
Noncollision (93)	Unbelted	22	46	15
Noncollision (93)	Belted	26	54	
Noncollision (93)	Unknown	45		
Collision with Nonfixed Object (35)	Unbelted	18	69	6
Collision with Nonfixed Object (35)	Belted	8	31	
Collision with Nonfixed Object (35)	Unknown	9		
Total		**602**		**100**

Source: FARS 2005 data.

In order to provide further insight into the rate of fatality for the crash events shown in Tables 12 and 13, Tables 14 and 15 present the number of nonfatal crashes that occur within each category. The ratio of fatalities to nonfatal crash involvement provides an indication of the relative severity of each crash condition. The crash-involved driver and injured driver counts shown in the tables are based on data from the NASS General Estimates System (GES). The NASS GES is a population-based sample of police-reported crashes occurring across the United States. Each year, approximately 55,000 raw cases are sampled from 60 primary sampling units selected to represent the national crash experience. The case data include information collected by police as observed on-the-scene and information reported by crash-involved occupants. No further crash investigation or reconstruction is conducted beyond collection of police-reported information. The NASS GES sampling criteria include crash events of lower severity, including property-damage-only crashes, and minor, moderate, and severe injury crashes. The data are sampled and weighted such that the cases represent all police-reported crashes occurring on public roadways involving all vehicles types (including passenger vehicles as well as large trucks and buses).

Table 14 and Table 15 show that the majority of crash-involved vehicles found in NASS GES are vehicle-to-vehicle crashes (75 percent for drivers of all large trucks and for drivers of Class 7 and 8 trucks), yet rollovers claim the highest percentage of fatalities. Tables 14 and 15 are derived from GES and FARS data and include a breakdown of events in which all large trucks and Class 7 and 8 vehicles are involved. These events include rollovers, vehicle-to-vehicle collisions, fixed-object collisions, noncollisions, and collisions with nonfixed objects. These tables do not include a breakdown of safety-belt-use information, due to the inherent inaccuracies associated with police-reported safety-belt-use data in NASS GES. As shown in column 4 of Table 14, it is clear that rollovers result in the highest number of fatalities per crash involvement—2.89 percent of the rollover crashes involving all large trucks resulted in a fatality. This is considerably higher than the 0.28 percent fatality rate for all crashes involving all large trucks, as shown in the bottom row of Table 14.

Table 14. Distribution of Harmful Event Categories for Drivers of All Large Trucks, Both Unbelted and Belted

Most Harmful Event	Crash-Involved Drivers, number (%)	Injured Drivers, number (%)	Fatally Injured Drivers, number (%)	Fatalities per Crash-Involved Driver (%)
Rollover	8,649 (4%)	4,432 (37%)	250 (36%)	2.89
Vehicle-to-Vehicle	180,212 (75%)	5,387 (45%)	163 (24%)	0.09
Collision with Fixed Object	20,292 (8%)	1,328(11%)	139 (20%)	0.68
Noncollision (e.g., jackknife, fire)	14,329 (6%)	486 (4%)	99 (14%)	0.69
Collision with Nonfixed Object	17,044 (7%)	314 (3)	37 (5%)	0.22
Total	**240,526**	**11,947**	**688**	**0.28 (avg.)**

Source: GES 2005 and FARS 2005 data.

For Class 7 and 8 trucks (see Table 15), a similar rate of fatality is found. Rollovers result in the highest number of fatalities per crash involvement; 2.70 percent of the rollover crashes involving Class 7 and 8 vehicle trucks result in a fatality, compared to the overall average of 0.30 percent for all crashes combined. Based on Table 15, it is also clear that vehicle-to-vehicle crashes result in the fewest number of fatalities in the truck per crash involvement. This reflects the fact that the majority of vehicle-to-vehicle collisions involved a large truck coming in contact with a passenger vehicle.

Table 15. Distribution of Harmful Event Categories for Drivers of Class 7 and 8 Trucks, Both Unbelted and Belted

Most Harmful Event	Crash-Involved Drivers, number (%)	Injured Drivers, number (%)	Fatally Injured Drivers, number (%)	Percent of Crashes Involving a Fatality (%)
Rollover	8,251 (4%)	4,230 (39%)	223 (37%)	2.70
Vehicle-to-Vehicle	147,123 (75%)	4,699 (43%)	132 (22%)	0.09
Collision with Fixed Object	18,172 (9%)	1,095 (10%)	119 (20%)	0.65
Noncollision (e.g., jackknife, fire)	11,919 (6%)	486 (4%)	93 (15%)	0.78
Collision with Nonfixed Object	11,087 (6%)	314 (3%)	35 (6%)	0.32
Total	**196,552**	**10,824**	**602**	**0.30 (avg.)**

Source: GES 2005 and FARS 2005 data.

Table 16 and Table 17 indicate the distribution of vehicle damage severities coded in the FARS database for belted and unbelted drivers of all large trucks and of Class 7 and 8 vehicles, respectively. The tables suggest that 95 percent of fatal crashes for all large trucks involve disabling damage to the vehicle, according to FARS researchers. For Class 7 and 8 trucks as shown in Table 17, some 96 percent were reported as having disabling damage. When populations of belted versus unbelted drivers are considered, little difference can be observed in the proportion with disabling versus functional damage, and it is likely that there are differences in crash severity that are not discernible. Some crashes in which the truck is coded as having disabling damage may be truly nonsurvivable for drivers of the large truck. Others may result in disabling damage, yet the vehicle occupant compartment remains intact. In identifying cases in which drivers would have survived had they worn their safety belts, the FARS data are of little use. Few additional data are collected by FARS researchers to accurately characterize the survival space and determine the mechanism of driver injury that led to death. Within section 7.2, alternate sources are explored to determine how many fatally injured drivers of large trucks would have survived had they been wearing safety belts.

Table 16. Vehicle Damage Severity Coded in FARS for Belted and Unbelted Drivers of All Large Trucks

	Unknown	Unbelted	Belted	Total Number (% of total)
Disabling	117	316	219	652 (95%)
Functional	1	13	12	26 (4%)
Other, Minor	0	4	0	4 (>1%)
None	0	3	0	3 (>1%)
Unknown	0	1	2	3 (>1%)
Total	**118**	**337**	**233**	**688**

Source: FARS 2005 data.

Table 17. Vehicle Damage Severity Coded in FARS for Belted and Unbelted Drivers of Class 7 and 8 Trucks

	Unknown	Unbelted	Belted	Total Number (% of total)
Disabling	115	266	196	577 (96%)
Functional	1	8	7	16 (3%)
Other, Minor	0	4	0	4 (>1%)
Unknown	0	1	2	3 (>1%)
None	0	2	0	2 (>1%)
Total	**116**	**281**	**205**	**602**

Source: FARS 2005 data.

7.1.2. Crash Environment Characteristics

Roadway Types

Table 18 and Table 19 show the distribution of crashes for all large trucks and for Class 7 and 8 trucks by roadway type. Table 18 shows the number of fatalities for drivers of all large trucks by roadway type. FARS data indicated that the majority of fatal crashes (82 percent) in 2005 occurred on highways, which includes interstates (40 percent), state highways (24 percent), and U.S. highways (19 percent). For those crashes in which the safety belt status was known, overall, 59 percent were unbelted. The highest unbelted rate (known safety belt status) for drivers of all large trucks (10,001 pounds or more) was on municipality roadways (85 percent), followed by county roads, where 80 percent were unbelted. Table 19 shows similar results for Class 7 and 8 drivers; drivers were unbelted in 58 percent of the fatal crashes in which the safety belt status was known. Forty-eight percent of Class 7 and Class 8 truck drivers who were fatally injured on interstate roadways were unbelted.

Table 18. Fatal Crashes by Roadway Type for Drivers of All Large Trucks

Roadway Type	Unknown Safety Belt Status	Unbelted	Belted	Unbelted, Known Safety Belt Status (%)	Total Number (% of total)
Interstate	60	104	109	49	273 (40%)
State Highway	21	84	57	60	162 (24%)
U.S. Highway	23	64	42	60	129 (19%)
County Road	7	45	11	80	63 (9%)
Other Local	6	10	5	67	21 (3%)
Municipality	0	17	3	85	20 (3%)
Other	1	13	6	68	20 (3%)
Total	**118**	**337**	**233**	**59 (avg.)**	**688**

Source: FARS 2005 data.

Table 19. Fatal Crashes by Roadway Type for Drivers of Class 7 and 8 Trucks

Roadway Type	Unknown Safety Belt Status	Unbelted	Belted	Unbelted, Known Safety Belt Status (%)	Total Number (% of total)
Interstate	60	92	101	48	253 (42%)
State Highway	20	72	46	61	138 (23%)
U.S. Highway	22	52	39	57	113(19%)
County Road	7	37	8	82	52 (9%)
Other Local	6	6	4	60	16 (3%)
Municipality	0	12	2	86	14 (2%)
Other	1	10	5	67	16 (3%)
Total	**116**	**281**	**205**	**58 (avg.)**	**602**

Source: FARS 2005 data.

Weather Conditions

In 2005, the majority of the fatal CMV crashes occurred in “normal” weather conditions (88 percent), as opposed to rainy (8 percent) or foggy (2 percent) weather. Table 20 and Table 21 show that there are few differences based on weather conditions between the belted and unbelted CMV driver populations for all large trucks and Class 7 and 8 trucks, respectively.

Table 20. Fatal Crashes by Weather Conditions for Drivers of All Large Trucks

Weather Conditions	Unknown Safety Belt Status	Unbelted	Belted	Unbelted, Known Safety Belt Status (%)	Total Number (% of total)
Normal	98	301	204	60	603 (88%)
Rain	12	28	13	68	53 (8%)
Fog	3	5	7	42	15 (2%)
Snow	3	3	4	43	10 (1%)
Other	1	0	5	0	6 (<1%)
Sleet	1	0	0		1 (<1%)
Total	**118**	**337**	**233**	**59 (avg.)**	**688**

Source: FARS 2005 data.

Table 21. Fatal Crashes by Weather Conditions for Drivers of Class 7 and 8 Trucks

Weather Conditions	Unknown Safety Belt Status	Unbelted	Belted	Unbelted, Known Safety Belt Status (%)	Total Number (% of total)
Normal	96	249	180	58	525 (87%)
Rain	12	24	10	71	46 (8%)
Fog	3	5	6	45	14 (2%)
Snow	3	3	4	43	10 (1%)
Other	1	0	5	0	6 (<1%)
Sleet	1	0	0		1(<1%)
Total	**116**	**281**	**205**	**58 (avg.)**	**602**

Source: FARS 2005 data.

Time of Day

Data shown in Figure 6 and Table 22 were aggregated for 2000–2005 data years to compile sufficient crash counts by hour to identify trends. Figure 6 shows that overall, driver fatalities most often occur during daytime hours (i.e., from 5 a.m. to 4 p.m.), and decline after 5 p.m.

As shown in Table 22, within the population of fatally injured drivers of all large trucks, the lowest rate of safety belt use occurred from 3 p.m. to 6 p.m., when only 33 percent were belted. From 6 p.m. to 9 p.m., the belted percentage increased to 39 percent. From 9 p.m. to 12 p.m., 41 percent were belted. From midnight to 3 a.m., the highest rates of safety belt use in the fatally injured population are observed—43 percent are belted. From 3 a.m. to 6 a.m., 42 percent are belted. From 6 a.m. to 9 a.m., the belted percentage drops to 38 percent. From 9 a.m. to 12 a.m., the percent of belted declines further to 36 percent. From noon to 3 p.m., this population is 35 percent belted. When the percentage of belted drivers who die during nighttime crashes is compared with the proportion of drivers who die during daytime crashes, it appears that a larger proportion is belted at night. This is somewhat counterintuitive, since the risk of safety-belt-use enforcement should be higher during the day.

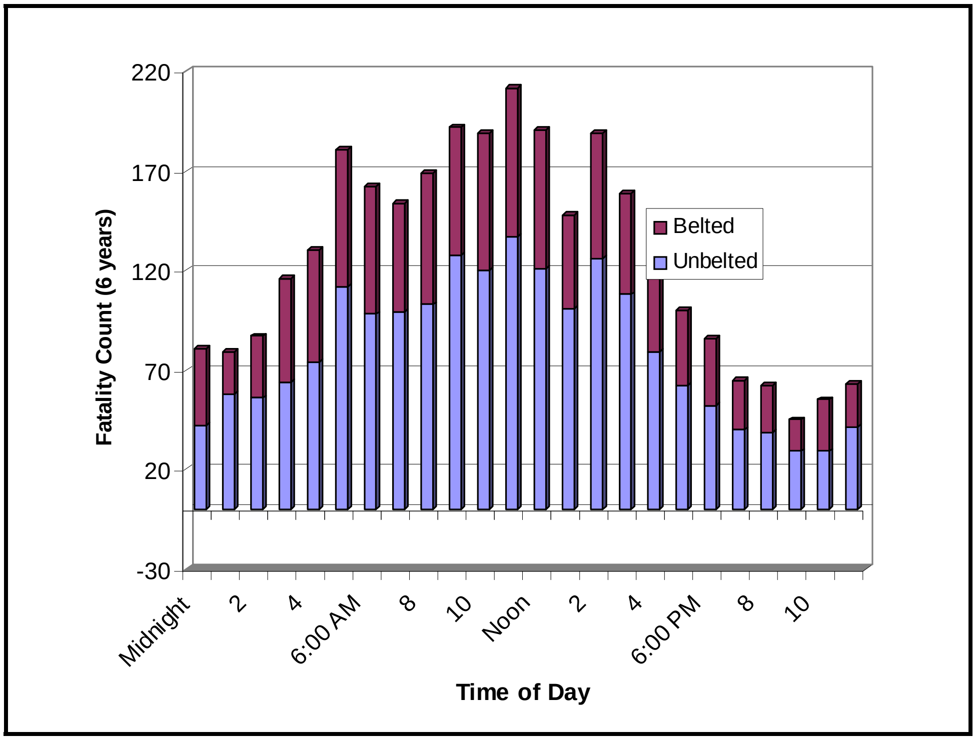

Figure 6. Fatalities by Time of Day and Belt Use for Drivers of All Large Trucks

Source: FARS 2000–2005 data.

Table 22. Fatalities by Time of Day and Belt Use for All Large Trucks

Crash Time	Unbelted, number (%)	Belted, number (%)
Midnight to 3 a.m.	126 (57%)	94 (43%)
3 a.m. to 6 a.m.	233 (58%)	170 (42%)
6 a.m. to 9 a.m.	263 (62%)	160 (38%)
9 a.m. to 12 a.m.	329 (64%)	182 (36%)
Noon to 3 p.m.	285 (65%)	156 (35%)
3 p.m. to 6 p.m.	224 (67%)	109 (33%)
6 p.m. to 6 p.m.	117 (61%)	76 (39%)
9 p.m. to 12 p.m.	88 (59%)	60 (41%)

Source: FARS 2000–2005 data.

The distribution of fatal crashes by time of day for Class 7 and 8 truck drivers is nearly identical to that shown in Figure 6 and Table 22. For this reason, these items are not presented here.

7.1.3. Crash Vehicle Characteristics

Table 23 shows the distribution of 2005 fatalities by cargo body type and by vehicle configuration (i.e., tractor trailer or single-unit truck). As shown, the majority of driver fatalities involve tractor trailers with a cargo body type designated as “van/enclosed box.”. It should be noted that according to FHWA Annual Vehicle Distance Traveled statistics, each tractor trailer (Class 8 truck) travels an average of 74,245 miles per year, compared to 13,164 miles of annual travel for single-unit trucks. Due in part to this higher level of exposure, tractor trailers are more often involved in fatal crashes. Combination trucks are more often operated on higher-speed roadways (highways). It should be noted that even a slight increase in safety belt use by Class 8 truck drivers will have a greater impact on injury and fatality counts for CMV drivers as compared to other vehicle segments (like smaller single-unit trucks). If 10 percent of the unbelted fatal population of tractor trailer drivers were belted during their crashes, 265 drivers would be affected (55 percent of 481 fatal drivers). However, if 10 percent of the unbelted fatally injured population of Class 7 single-unit truck drivers wore their belts, only 82 drivers would be affected (68 percent of 121 fatal drivers).

Table 23 also shows that a larger percentage of single-unit-truck driver fatalities are sustained by unbelted drivers (68 percent of single-unit-truck fatalities are unbelted versus 55 percent of fatal truck/tractor drivers are unbelted). These percentages include fatal crashes where the driver's safety belt status was known. The unbelted percentages shown in columns 3, 5, and 7 of Table 23 were calculated by dividing the number of unbelted fatally injured drivers by the number of fatally injured drivers whose safety belt use status was known for each vehicle configuration listed in the table. Each vehicle type category was derived directly from FARS-coded vehicle types.

Table 23. Distribution of Driver Fatalities in 2005—Vehicle Configuration versus Cargo

CARGO (Type 1)	(Class 8) Fatalities	(Class 8) Unbelted, Known Safety Belt Status (%)	(Class 7) Fatalities	(Class 7) Unbelted, Known Safety Belt Status (%)	(Non-Class 7 and 8) Fatalities	(Non-Class 7 and 8) Unbelted, Known Safety Belt Status (%)
Van/Enclosed Box	240	51	33	63	41	64
Flatbed	58	48	11	59	17	71
Cargo Tank	72	57	9	83	4	100
Dump	27	59	33	69	6	67
Unknown Truck	23	69	7	80	10	70
Other Truck	25	62	6	91	6	80
No Cargo Body	12	70	1	0	2	0
Garbage/Refuse	5	66	9	100	0	0
Grain/Gravel, etc.	12	64	2	50	0	0
Concrete Mixer	0	0	10	70	0	0
Pole	6	83	0	0	0	0
Total	**481**	**55**	**121**	**68**	**86**	**67**

[1]Vehicle types reported here are based on FARS 2005 codes. Source: FARS 2005 data.

Key: Class 8—Tractor Trailer, Class 7—Single-Unit Truck, Non-Class 7 and 8—Large Trucks (>10,000 pounds)

7.1.4. Crash Occupant Characteristics

Figure 7 shows the distribution of fatalities for drivers of all large trucks by age and safety belt use for the years 1995, 2000, and 2005. Within the youngest age category (drivers aged 20 to 34 years), the total number of fatalities decreased from 137 in 1995 to 108 in 2005. Conversely, for drivers aged 50 and older, the total number of fatalities increased from 153 in 1995 to 248 in 2005. The increase in fatalities for drivers older than 50 years may reflect a general increase in the average age of drivers since 1995. The middle-aged group does not show any clear trend when 1995, 2000, and 2005 crash years are compared.

When safety belt use is considered, the percent of unbelted drivers dying in crashes appears to have decreased since 1995 for all age groups. Overall, the youngest group of drivers (aged 20 to 34) has the highest percentage of unbelted drivers when compared to the middle-aged and older age groups. This is true across all three years considered.

The injury tolerance of older drivers is typically lower than that of the young and may influence the fatality rates shown here. If an older driver is involved in a crash of identical severity to that of a younger driver, the likelihood of death is higher for the older driver. It is possible that younger unbelted drivers may be surviving crashes that their older counterparts do not survive, and for this reason it is possible that the youngest drivers are unbelted even more frequently than suggested by Figure 7, when compared to the older group (50+ years old).

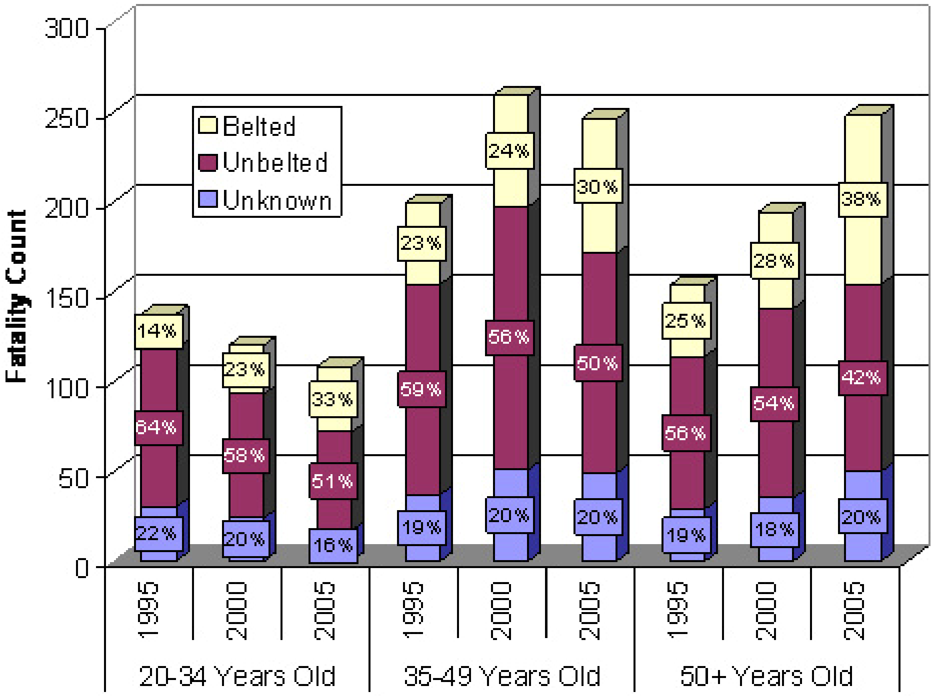

Figure 7. Distribution of Class 7 and 8 Truck Driver Fatalities
Source: FARS 2005.

When driver gender was considered, it was discovered that only 22 of the 602 fatally injured drivers were females for Class 7 and 8 vehicles. For all large trucks, only 24 of the 688 drivers were female. The data indicated that, for Class 7 and 8 drivers, 36 percent (8 out of 22 fatally injured female drivers) were unbelted and for all large trucks, 33 percent (8 out of 24 fatally injured female drivers) of this small population was unbelted. This percentage of unbelted drivers is considerably lower when compared to the 60 percent of male drivers who are unbelted;

however, few reliable conclusions can be drawn from this difference due to the small number of female driver observations within the FARS dataset used to make the comparison.

The impact of medical issues on fatalities was explored, including heart attacks, loss of consciousness, or other conditions where driver performance is affected. In 2005, FARS analysts indicated that medical conditions (including diabetic reactions, seizure, heart attack, high/low blood pressure, and fainting) were a crash-related factor in seven of the 602 Class 7 and 8 truck driver fatalities. It should be noted that the determination of medical factors is not straightforward, and this population may under-represent the actual impact of medical-related events.

For the fatal population, few data are recorded by FARS analysts to describe the health of drivers. One health surrogate that can be calculated based on FARS data is the Body Mass Index or BMI. BMI is calculated by dividing body weight in kilograms by body height in meters squared and can be used as a surrogate measure of fitness for drivers. A BMI less than 27 is considered normal. A BMI between 27 and 31 is considered overweight and over 31 is considered obese. Figure 8 shows the distribution of BMI for fatally injured CMV drivers. As shown in Figure 8, some 53 out of a total of 84 (63 percent) normal BMI drivers were unbelted. For obese drivers, 98 out of 158 (62 percent) are unbelted. One claim made by drivers is that current safety belts do not comfortably fit larger or obese drivers and this leads to lower safety belt use rates by this demographic population. Compared with normal BMI drivers, the fatally injured population of overweight and obese drivers does not appear to contain larger proportions of unbelted drivers. It should be noted that BMI is only an approximation of driver size.

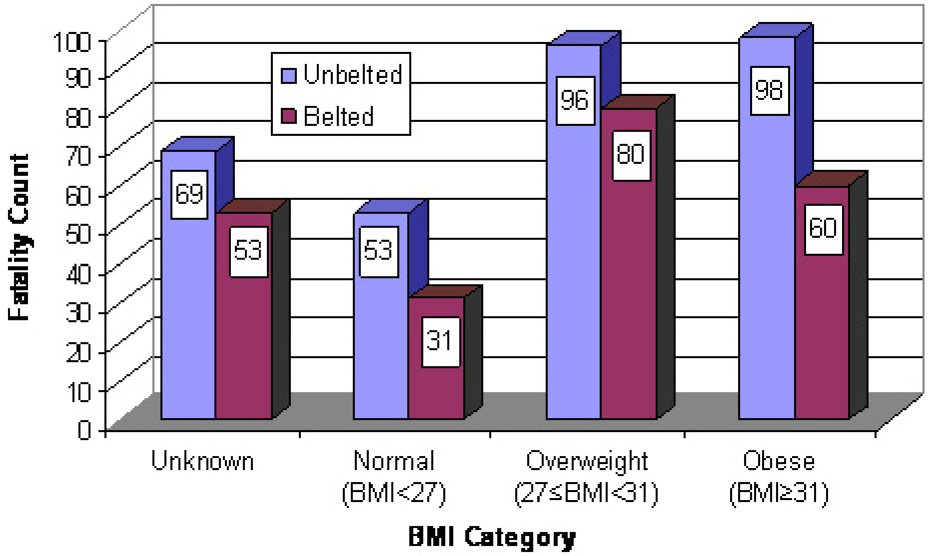

Figure 8. Driver Body Mass Index (BMI) for Fatally Injured Drivers of All Large Trucks
Source: FARS 2005 data. Note: BMI is an approximation of driver size.

7.2. CHARACTERISTICS OF FATALLY INJURED AND BELTED CMV DRIVERS

Safety belts have been proven to be the most effective strategy to prevent fatalities for motor vehicle drivers and passengers; however, 41 percent of CMV drivers who died during crashes in 2005 were wearing safety belts. These data were presented above, in Figure 6. The following analysis was conducted to better understand mechanisms of fatal injury for belted drivers, and how these fatal crashes involving belted drivers differ from other crashes in which belted drivers survived.

To accomplish this, it was necessary to go beyond general characteristics of crashes as described previously and determine the primary sources or mechanisms of injury for fatal drivers. Unfortunately, within the FARS data, little information is collected to characterize the postcrash condition of vehicles, characteristics of the occupant compartment, and the mechanism of injury leading to death.

In order to adequately assess this information, a review of the Large Truck Crash Causation Study (LTCCS) dataset was conducted as a part of this research. The dataset, described in more detail below, contains accurate information regarding crash conditions, the nature of injuries sustained, and the overall severity of each crash case collected. The analysis that was performed reviewed mechanisms for incapacitating and fatal injury cases. Incapacitating injury cases were reviewed along with fatal cases because the LTCCS data contain only a small sample of fatally injured driver cases. It was confirmed during the analysis that the conditions leading to serious injuries are similar to those resulting in death. In sections 7.2.3 and 7.2.4, an example case review and the findings from reviewing all of the unbelted fatal and serious-injury cases are provided to identify whether those fatally and seriously injured drivers would have sustained the same or lesser injuries had they been belted.

7.2.1. Large Truck Crash Causation Study Data

The LTCCS contains a sample of crashes where at least one large truck with a GVWR of 10,001 pounds or more was involved in a crash that resulted in at least one K-, A-, or B-level injury. These are crashes in which one or more fatalities (K), an incapacitating injury (A), or a non-incapacitating (but evident) injury (B) were or was sustained by any occupant involved. Data for the sample were collected by National Accident Sampling System (NASS) personnel across 17 sampling sites. Based on its probability of selection, each case collected was assigned a weighting factor and when weights were applied, it was possible to compute estimates that were representative of K-, A-, and B-level crashes involving large trucks across the entire country.

The LTCCS dataset is a useful resource for this analysis due to the highly detailed data collected per case. As a result of ongoing cooperation with police in the 17 data collection sites around the country, researchers were rapidly informed of large-truck crashes and were able to initiate investigations soon after each crash occurred. Data collection was performed at each crash site by a two-person team consisting of a trained NASS researcher and a state truck inspector. While on the scene, crash-involved vehicle occupants and witnesses were interviewed. After the crash, each vehicle was subjected to a thorough inspection. Researchers also reviewed police crash reports, hospitals records, and coroners’ reports. For each case, up to 1,000 data elements were collected and coded. In addition, the crash scene and post-impact vehicles were photographed extensively to document conditions. A scene sketch, drawn to scale, also provided a graphical overview of the environment, the crash scenario, and all known impact events.

Table 24 and Table 25 provide a summary of LTCCS case counts by level of injury sustained by drivers. All individual injuries coded within the LTCCS are assigned an AIS code that uniquely identifies the body region, the details related to the anatomical structure involved, and the severity of the injury sustained. The AIS severity indicates the threat to life associated with a particular injury and ranges from 0 to 6 (where AIS 0 is uninjured, AIS 1 injury is minor, AIS 2 is moderate, AIS 3 is serious, AIS 4 is severe, AIS 5 is critical, and AIS 6 is maximum or generally nonsurvivable). Results shown in the table are reported by maximum AIS (MAIS) per driver. Each driver is represented only once in the table based on his or her most severe injury, even if he or she sustained multiple injuries during the crash.

The unweighted numbers in Table 24 indicate the raw number of cases collected by LTCCS investigators. Weighted counts in Table 25indicate national level estimates of large-truck crash counts where a K-, A-, or B-level injury was sustained by an occupant involved. Since it is impossible to conduct a detailed investigation of every truck crash occurring within the United States, a sample of crashes is selected and investigated. In order to relate those observations selected and investigated to the actual crash population, weights are assigned to each case. The sum of the weights for all cases reflects the total number of actual large-truck crashes occurring within the study period.

Weighted and unweighted numbers are presented in Table 24 and Table 25 so that the reader is aware of the limited sample size with which this analysis was conducted. As shown in Table 24, the number of cases available where a moderate to serious injury was sustained by the large-truck driver is relatively small, including 59 MAIS 2 injured, 33 MAIS 3, 9 MAIS 4 , 4 MAIS 5 and 43 MAIS 6 or fatally injured drivers. The population of injured is quite small compared to the population of uninjured and those who sustained only minor injuries. For this reason, in reviewing moderate- to serious-injury cases, only unweighted case counts are presented. Application of case weights to a small population of cases would likely result in spurious or unreliable estimates.

As shown in Table 24 and Table 25, there are 64 unweighted cases where a belted driver sustained at least one AIS 2 or higher injury. These cases were selected for detailed review to determine the primary cause of the most serious injuries sustained.

Table 24. Unweighted Driver Counts by MAIS Injury Levelfor Drivers of All Large Trucks

MAIS Level	Unknown	Unbelted	Belted	Total
Uninjured	56	83	628	767
Minor (MAIS 1)	12	78	219	309
Moderate (MAIS 2)	4	23	32	59
Serious (MAIS 3)	-	14	19	33
Severe (MAIS 4)	-	5	4	9
Critical (MAIS 5)	1	2	1	4
Maximum (MAIS 6)	12	23	8	43
Total	**85**	**228**	**911**	**1,224**

Source: LTCCS 2000–2003 data.

Table 25. Weighted Driver Counts by MAIS Injury Level for Drivers of All Large Trucks

MAIS Level	Unknown	Unbelted	Belted	Total
Uninjured	4,384	7,484	64,421	76,288
Minor (MAIS 1)	935	11,484	30,091	42,510
Moderate (MAIS 2)	1,041	4,394	4,695	10,130
Serious (MAIS 3)	-	3,356	2,241	5,597
Severe (MAIS 4)	-	759	815	1,574
Critical (MAIS 5)	39	321	160	520
Maximum (MAIS 6)	721	908	457	2,086
Total	**7,120**	**28,706**	**102,880**	**138,704**

Source: LTCCS 2000–2003 data.

For each injured driver, a list of the injuries sustained was first compiled and sorted by body region involved (i.e., head, chest, abdomen, upper extremity, or lower extremity). For each unique injury coded, LTCCS researchers indicated the source of injury that identifies the interior or exterior component that most likely caused the injury. In addition, the code indicates if the injury was a noncontact injury. One missing data element in the LTCCS dataset is the degree of damage sustained by the truck. In particular, intrusion or collapse of the occupant survival space is not well-defined. In order to characterize the postcrash condition of the truck compartment, a case-by-case review of compartment photos was conducted and the damage severity was coded for the region immediately surrounding the occupant.

There were 24 rollover crashes involving belted drivers within the LTCCS file in which MAIS 2 and higher injuries occurred. Based on information gathered during the review, significant roof-crush and side structural damage occurred during all of these events. The resulting injuries were related to the intrusion. The LTCCS dataset contains 20 vehicle-to-vehicle crashes in which the driver sustained MAIS 2 and higher injuries. Based on clinical case reviews, it was determined that the majority of impact events involved the front of the case vehicle striking the rear of another truck. For each vehicle-to-fixed-object-collision reviewed, significant occupant compartment intrusion occurred or belted drivers were partially ejected, interacting with objects outside of the vehicle. Only two cases of vehicle–to-nonfixed-objects interaction were identified. One involved a train collision in which serious damage was sustained by the truck. The second involved a driver who was believed to have had a heart attack before the crash occurred.

With the exception of the case of the driver who sustained a heart attack prior to the crash, the review showed that severe compartment intrusion was present for all frontal crash cases in which an MAIS 2 or higher injury was sustained. It should be noted that no cases were discovered where injuries were caused by driver interaction with the safety belts only. In all cases, direct contact injuries (with intruding interior or exterior components) were sustained.

For cases in which side-loading occurred (during vehicle-to-vehicle or rollover collisions onto the vehicle’s side), safety belts were not effective in preventing serious injury or death. There were 14 cases identified within the LTCCS dataset in which a belted driver sustained a moderate to serious injury under these conditions.

7.2.2. Preventable Injuries and Fatalities with Safety Belt Use

Further analysis of the LTCCS dataset was conducted to determine what impact safety belt use would have had on the population of unbelted drivers who were fatally or seriously injured during truck crashes. This evaluation was performed to address misconceptions regarding safety belts that were voiced by the stakeholders. One misconception is that safety belts will have little influence during large-truck-versus-passenger-vehicle crashes, because large trucks have a size advantage. Another misconception is that in crashes where an unbelted driver dies, the crashes are so severe that drivers are not likely to survive even with safety belt use.

A detailed analysis of 70 crash cases was conducted where an unbelted large-truck driver was seriously injured or fatally injured during a crash. Clinical case reviews were conducted to determine what effect, if any, safety belt use would have had on a population of fatally and seriously injured CMV drivers who were not wearing safety belts. Case reviews were performed by two research team members with considerable backgrounds in crash analysis. The analysis was performed separately by each reviewer and results were compared for accuracy. All differences of opinion were discussed and re-categorized as agreed upon by both researchers.

For each driver injured or killed, a list of the injuries sustained was generated and sorted by body region. For each unique injury coded, an injury source was also determined that identified the interior or exterior component that most likely caused the injury. In addition, the code indicates whether the injury was a contact or non-contact injury. This information is useful in determining the occupant kinematics or movement within a vehicle during a crash; however, no indication of intrusion or crash-induced interior damage to the truck is coded. For instance, if the steering-wheel rim was coded as the injury source for a particular chest injury, it is not possible to determine from the coded data if the steering-wheel rim intruded into the occupant’s survival space leading to the injury or if the unrestrained occupant made harmful contact with the steering column due to crash forces.

To better understand the crash environment in which the injury occurred, interior and exterior vehicle crash photos were reviewed to estimate if direct contact with the injury source component would have occurred if the driver had been belted. For injuries that were AIS 2 and higher, injured body regions for unbelted occupants were categorized as preventable, possibly preventable, or non-preventable categories. In some cases, severe occupant compartment intrusions at the driver’s seating position occurred and the use of a safety belt would not likely have reduced the severity of injuries. Alternatively, if the vehicle interior structure remained intact and the survival space was maintained, direct contact injuries are flagged as potentially preventable or preventable if belted.

Exterior damage was also assessed using vehicle photos to establish if crash forces were sufficiently severe that safety belt use would not have prevented or mitigated injuries, even in the absence of significant compartment intrusion in the area of the driver’s seating position.

As mentioned above, a large amount of data is coded for each LTCCS case; however, few measurable indicators of crash severity are collected for truck crashes. Traditional information, like crash deltaV, degree of compartment intrusion, and intrusion extent by component are unrecorded for truck crashes.

7.2.3. Example Case Review

Described in this section is an example of a case review involving a severely injured (MAIS 4), unbelted CMV driver who would likely have sustained only minor injuries during the crash had he been belted. LTCCS Case #813006030 occurred on a two-lane highway under rainy conditions. It involved two tractor trailers traveling in opposite directions. The collision was an offset frontal crash. This was evident by the external damage to both trucks.

Within the two trucks were the drivers, one belted and one unbelted, and two passengers both of whom were belted. The belted occupants all sustained minor injuries (all AIS 1). The unbelted driver of the case vehicle was a 52-year-old male who sustained one AIS 4 injury and several AIS 3 injuries. His injuries included multiple rib fractures, associated hemo/pneumothorax, a lung contusion, and a splenic laceration. Each of these injuries was attributed to contact with the steering wheel and vehicle side structure during the offset collision. During the collision, this unbelted driver significantly interacted with the steering wheel (as evidenced by severe deformation of the steering wheel and column). This driver also sustained a loss of consciousness due to interaction with the steering mechanism or due to contact with the roof header. Four photographs, shown in Figure 9, Figure 10, Figure 11, and Figure 12, show the severity of the crash.

Figure 9. Interior Photo of Case Vehicle Showing Extensive Steering Deformation

Source: 2000–2003 LTCCS data.

Figure 10. Interior Photo of the Principal Other Vehicle (Crash Partner) Showing no Steering Deformation
Source: LTCCS 2000–2003 data.


[redacted]

Figure 11. Exterior View of Case Vehicle Where Unbelted Driver Was Severely Injured (MAIS 4) and Belted Passenger Sustained Minor Injuries (MAIS 1)
Source: LTCCS 2000–2003 data.

[redacted]

Figure 12. Exterior View of Principal Other Vehicle Where Both Belted Occupants Sustained Minor Injuries (MAIS 1)
Source: LTCCS 2000–2003 data.

Based on the vehicle photos, no passenger compartment intrusion occurred in either vehicle. The external damage is consistent with a frontal offset collision with a similar vehicle. The belted driver sustained only minor injuries during the crash and his steering wheel and column remained undamaged. Had the severely injured driver been belted, it is less likely that he would have come in contact with the steering column and rim. If he had, the degree of loading would have been significantly lower. This case shows that the use of a safety belt could have made a significant difference in the injury outcome for the CMV driver.

7.2.4. Case Review Results

Crashes from the LTCCS dataset in which unbelted CMV drivers were either severely injured or fatally injured were reviewed for the purpose of determining if the safety belt use would have mitigated the injury sustained or prevented a fatality from occurring. As shown in column 3 of Table 26, some 37 out of the 70 fatal- or serious-injury cases reviewed would have improved outcomes with belt use. For these cases, this included preventable deaths and injuries that might have been mitigated. Twenty-eight of the 47 moderate, serious, severe, or critical injuries (MAIS 2 through MAIS 5) could have been mitigated to minor injuries with safety belt use, as shown in Table 26. Also shown in the table is that nine out of 23 fatalities (MAIS 6) would likely have been prevented if the driver had used the safety belt. These results are also shown with weighted values in Table 27.

Table 26. Potentially Preventable Deaths and Reduced Injuries if Safety Belts Had Been Used—Unweighted Counts

Unweighted Counts	Maybe	No	Yes (% MAIS)	Total
No Injury	0	0	0	0
Minor Injury (MAIS 1)	0	0	0	0
Moderate Injury (MAIS 2)	0	8 (35%)	15 (65%)	23
Serious (MAIS 3)	2 (13%)	6 (40%)	7 (47%)	15
Severe (MAIS 4)	0	2 (29%)	5 (71%)	7
Critical (MAIS 5)	0	1 (50%)	1 (50%)	2
Fatal (MAIS 6)	2 (9%)	12 (52%)	9 (39%)	23
Total	**4 (6%)**	**29 (41%)**	**37 (53%)**	**70**

Source: LTCCS 2001–2003 data.

Table 27. Potentially Preventable Deaths and Reduced Injuries if Safety Belts Had Been Used—Weighted Counts

Weighted Counts	Maybe	No	Yes (% MAIS)	Total
No Injury	0	0	0	0
Minor Injury (MAIS 1)	0	0	0	0
Moderate Injury (MAIS 2)	0	1,538	2,856	4,394
Serious (MAIS 3)	770	1,281	1,503	3,554
Severe (MAIS 4)	0	33	1,475	1,508
Critical (MAIS 5)	0	0	321	321
Fatal (MAIS 6)	85	339	484	908
Total	**855**	**3,191**	**6,639**	**10,685**

Source: LTCCS 2001–2003 data.

Most of the injuries that could have been mitigated or prevented were due to contact with the interior passenger compartment and not to intrusion. Contacts with the vehicle steering wheel, shift lever, windshield, dashboard, side doors, windows, and roof were common injury sources for unbelted drivers. When occupant ejection is considered, there are a small number of vehicles that are considered too compromised for the crash to be called survivable. The largest proportion of ejected occupants would have survived if they had remained within the vehicle.

For unbelted occupants, column 4 in Table 28 shows that 19 (unweighted) of the unbelted drivers who sustained MAIS 2+ injuries were partially or fully ejected. Column 3 in Table 28 shows that based on this review of a small number of crash cases where complete or partial occupant ejection occurred, eight cases (42 percent of those ejected) are survivable and an additional three are potentially survivable, had the occupant been belted. The partial-ejection cases all involved partial ejection out of the driver side window where ground contact by the driver occurred during rollovers. During collisions with fixed objects and during vehicle-to-vehicle impacts, drivers made contact with components of a striking vehicle or fixed objects while remaining in their seats. Injuries sustained during these events could not have been prevented with safety belt use.

Table 28. Survivability by Ejection Occurrence for Unbelted Drivers Who Sustained MAIS 2+ Injuries—Effect of Safety Belt Use on Injury Mitigation

	Maybe	No	Yes	Total
Ejection Type (Unweighted)				
No Ejection	0	14 (45%)	17 (55%)	31
Complete or Partial Ejection	3 (16%)	8 (42%)	8 (42%)	19
Unknown	1 (5%)	6 (30%)	13 (65%)	20
Unweighted Total	**4 (6%)**	**28 (40%)**	**38 (54%)**	**70**
Ejection Type (Weighted)				
No Ejection	0	1,926	2,964	4,890
Complete or Partial Ejection	99	233	1,336	1,668
Unknown	756	1,032	2,339	4,127
Weighted Total	**855**	**3,191**	**6,639**	**10,685**

Source: LTCCS 2001–2003 data.

7.3. CHARACTERISTICS OF FATAL ROLLOVER CRASHES

Using the LTCCS dataset, a general analysis of fatal and nonfatal rollover crashes involving large trucks was conducted to better understand their primary characteristics and causes. For this analysis, a rollover was defined as any event involving “one or more quarter-turns about the longitudinal axis of a vehicle” and a planar crash was defined as any event in which the vehicle does not roll over.

An estimated 4 percent of all large-truck crashes involved rollovers, yet 223 drivers or 37 percent of all large-truck driver fatalities in 2005 occurred during crashes where rollover was identified as the most harmful event. An additional 96 drivers were fatally injured during crashes where a rollover occurred. In these cases, some other impact was classified as the most harmful event. The rate of fatality during rollovers is approximately three fatalities per 100 police-reported rollover crashes. This rate is four times higher than the fatality rate due to collisions with fixed objects and 25 times higher than the rate of fatality for drivers of large trucks during vehicle-to-vehicle collisions.

Table 29 shows the fatal occupant ejection counts for planar and rollover crashes by nonejected, ejected, belted, and unbelted CMV drivers. In 163 of the 319 rollover fatalities (51 percent), the occupants were unbelted. As shown in rows 2 and 5 of Table 29, within the unbelted group, 39 of these were drivers of single-unit trucks and 124 of these were drivers of tractor trailers (Class 8 trucks). Seventy-eight out of the 163 unbelted occupants (48 percent) were completely or partially ejected from the occupant survival space.

Table 29. Fatal Occupant Ejection Counts for Planar and Rollover Crashes of Class 7 and 8 Trucks

		Non-ejected	Ejected	Total
Rollover Crashes				
Single-Unit Truck	Unknown	9	3	12
Single-Unit Truck	Unbelted	18	21	39
Single-Unit Truck	Belted	25	0	25
Tractor Trailer	Unknown	26	11	37
Tractor Trailer	Unbelted	67	57	124
Tractor Trailer	Belted	75	7	82
Rollover Total				**319**
Non-rollover Crashes				
Single-Unit Truck	Unknown	1	1	2
Single-Unit Truck	Unbelted	21	13	34
Single-Unit Truck	Belted	9	0	9
Tractor Trailer	Unknown	49	17	66
Tractor Trailer	Unbelted	64	19	83
Tractor Trailer	Belted	81	8	89
Non-rollover Total				**283**

Source: FARS 2005 data.

In general, rollover crashes involving Class 7 and 8 trucks occur most frequently on rural high-speed roadways. Table 30, based on FARS 2005 data, indicates that 191 driver fatalities occurred in these locations, representing 60 percent of all fatal rollover crashes involving Class 7 and 8 trucks. This includes rural interstates (66 driver fatalities), rural state highways (79 driver fatalities), and rural U.S. highways (46 driver fatalities).

Table 30. Driver Fatality Counts During Rollover Crashes by Roadway Type for Class 7 and 8 Trucks

Roadway Type	Rural	Urban	Total
Interstate	66	36	102
State Highway	79	13	92
U.S. Highway	46	12	58
Total High-Speed Roadway	191	60	252
County Road	35	4	39
Other	11	2	13
Township	5	1	6
Municipality	0	5	5
Unknown	1	0	3
Frontage Road	1	0	1
Total Non-High-Speed Roadway	53	12	67
Total	**244**	**72**	**319**

Source: FARS 2005 data.

Table 31 shows FARS 2005 data of fatal rollovers by roadway alignment. These data suggest that fatal rollovers occur most often on straight roadways (51 percent) and most often involve tractor trailers. Table 32 identifies vehicle configurations involved in rollover crashes by cargo type in FARS 2005 data. As shown, tractor trailers hauling enclosed vans are the vehicle type most frequently involved in fatal rollovers, followed by tractor trailers hauling cargo tanks.

Table 31. Fatal Rollover Crashes by Roadway Alignment for Class 7 and 8 Trucks

Roadway Alignment	Truck with Tractor, Number (%)	Single-Unit Truck, Number (%)	Total Fatalities, Number (%)
Straight	131 (54%)	50 (66%)	181 (57%)
Curve	112 (46%)	25 (33%)	137 (43%)
Unknown	0	1 (<1%)	1 (<1%)
Total	**243**	**76**	**319**

Source: FARS 2005 data.

Table 32. Fatal Rollover Crashes by Vehicle Configuration and Cargo Type for Class 7 and 8 Trucks

Cargo Type[1]	Truck With Tractor	Single-Unit Truck
Van/Enclosed Box	102	15
Cargo Tank	55	8
Dump	20	23
Flatbed	23	7
Other Truck/Bus	13	4
Unknown Truck/Bus-type	8	3
Concrete Mixer	0	9
Garbage/Refuse	4	5
Grain/Gravel, etc.	8	1
No Cargo Body	7	1
Pole	3	0
Total	**243**	**76**

[1] Cargo types and vehicle configurations reported here are based on FARS 2005 data.

7.4. ROLLOVER CRASH CAUSATION

Rollover crashes occur under widely diverse conditions, and for each event, multiple causal factors are likely to play a part. Within the LTCCS dataset, the critical precrash event is selected by investigators, which is defined as the single event that made the crash unavoidable.

This event is typically a factor that directly precedes the initiation of the rollover; however, multiple additional factors might exist that, if changed, would have prevented the rollover from occurring. For example, if a rollover occurred while a truck was initiating a turn at an intersection, the critical precrash event might have been coded as "turning left at intersection." But if data collected on-scene indicated that the driver was inattentive and failed to recognize the upcoming intersection or that the driver might have been traveling too fast for an upcoming curve, then these conditions can also be considered causal factors.

It is difficult to analyze the chain of events leading to the onset of crashes like rollovers. Rather, a more useful approach is to identify all influential environmental-, vehicle-, or occupant-related causal factors for each case and later perform a factor analysis on the complete dataset to identify the most frequently recurring factors. This approach, applied in the following text, results in an expanded set of factors upon which to estimate crash causes for rollovers.

Table 33 shows the distribution of truck types involved in rollovers as coded in the LTCCS. As shown in the table, the majority of cases are rollovers involving combination trucks (147 unweighted cases). This trend reflects rollover involvement from the FARS (see Table 29). Physical causes, including those involving parts of the truck, the condition of the road, or elements of the surrounding environment, are generally apparent through study of the crash scene. However, the behavior of drivers is transitory, and the causes of the drivers' errors must be inferred through information supplied by witnesses coupled with detailed analysis of the crash scene. The depth of analysis employed in the LTCCS makes it unique in revealing events precipitating large-truck crashes. For each of the crashes, the database provides case narratives, diagrammatic representation of crash events, and scene photos to help in reconstructing the crash situations, allowing analysts to make inferences as to the cause.

Table 33. CMV Rollover Crashes by Body Type

Truck Type	Unweighted	Weighted Counts	Weighted % of Total
Combo Truck: Tractor Pulling Trailer	147	25,274	69
Single-Unit: Three or More Axles	43	4,913	13
Single-Unit: Two Axles	30	4,055	11
Combo Truck: Tractor Pulling Two Trailers	10	1,077	3
Combo Truck: Truck Pulling Trailers	5	665	2
Combo Truck: Truck Tractor Bobtail	5	286	1
Other/Unknown/Missing	2	230	1
Total	**242**	**36,500**	**100**

Source: LTCCS 2001–2003 data.

The underlying causes of 242 rollover incidents were analyzed—incidents which made up almost a quarter of the total LTCCS sample. The analysis was undertaken to isolate the specific causes of rollover crashes, which could be expected to vary significantly from those causes that prevailed across the full array of large-truck crashes. The differences could help to identify preventive approaches that are aimed specifically at reductions in rollovers.

The methodology employed in the rollover analysis included: (1) selecting the overall level of causation or reason category, (2) identifying causes, (3) aggregating causes, and (4) analyzing rollover results. The contributors to large-truck rollovers and the means used to identify them were analyzed at two levels.

One level addresses the immediate crash predecessors having a readily identifiable effect in leading to the crash. The LTCCS database revealed that about three-quarters of truck crashes were due to inadequacies of drivers in recognition of, decisions about, and performance in handling threats to safety encountered on the road. The remainder stemmed from problems involving the condition of drivers before the crash occurred, the vehicles being driven, the road being driven on, and the weather. The specific causes were identified by LTCCS investigators at the scene and through interviews with drivers and witnesses.

The second level of causation involves influences that are too remote in the causal chain to be identified through analysis of the crashes themselves. These include general characteristics of the driver (e.g., age, experience, and previous driving record), the vehicle (e.g., make, equipment), or the road (e.g., number of lanes, traffic controls). The effects of these influences, referred to as associated factors, were selected from a broad range of factors thought to contribute to crash risk. No judgment was made by LTCCS crash investigators as to whether any factor was related to the particular crash, just whether it was present (FMCSA, 2006).

During the review, the following major categories were identified that adequately characterize the types of influential factors observed. These include: speed, fatigue/attention/distraction, search, vehicle control, preoperative requirements, and other vehicles. Additional “causes” arose from problems with the vehicle that rolled over, including issues related to poor maintenance, load securement, and safety component failure. There were no problems with the road other than slippery surfaces, which only become a crash cause when drivers fail to adjust speed to surface friction. Since about two-thirds of the incidents involved more than one cause, the total frequencies of causes adds up to more than the number of rollovers. The individual causes, which make up the final classification system, are presented in the next section, along with the frequencies associated with each.

It should be noted that this review identified frequency of factors present when a rollover crash occurs based on unweighted LTCCS case counts. The review is intended to highlight the prevalence of each cause. The frequencies and population percentages presented should not be considered representative of the total CMV rollover crash population, due to the limited number of cases used to perform the analysis.

Most of the rollovers were the result of mistakes on the part of the truck drivers, although some were “caused” by drivers of other vehicles and by those responsible for loading the trucks. A small number of rollovers occurred due to problems with the vehicle itself. In most cases, the driver was aware of the particular problem and could have driven in such a manner as to prevent the rollover. In such instances, both the vehicle problem and the driver's failure to accommodate to it through safer driving were considered causes, since preventing either of them would have avoided the rollover. The same treatment is used for slippery or otherwise unsafe road surfaces, except that the only practical means of dealing with these is by adjusting speed and control of the vehicle accordingly. On some occasions, a rollover is the result of an unsuccessful attempt to overcome a situation created by an earlier error. For example, inattention can lead to a potential crash situation in which a driver avoids a collision by a quick turn. If the truck rolls over, the cause was the driver's inattention. The quick turn was not an error in this case, since it averted what would have been an equally serious, if not more serious, outcome. Table 34 shows the breakdown of "causes" of CMV rollovers identified in this LTCCS (2001–2003) review. As shown in the table, speed was the most frequent associated cause of rollover crashes (45 percent of LTCCS rollovers), followed by control-related (17 percent), and the category including fatigue, attention, and distraction (16 percent). Each of the categories shown in Table 34 and their subcategories are described in sections 7.4.1–7.4.7 in more detail. It should be noted that multiple causal factors may be assigned to each of the 242 rollover crashes, resulting in a total of 379 factors shown in Table 34.

Table 34. Causal Factors During CMV Rollover Crashes

Cause of CMV Rollover	Count	%
Speed	171	45
Fatigue, Attention, and Distraction	61	16
Control	66	17
Visual Search	9	3
Preoperation	22	6
Other Drivers	37	10
Vehicle	13	3
Total	**379**	**100**

Source: LTCCS 2001–2003 data.

7.4.1. Speed

Review of the LTCCS dataset (2001–2003) identified that speed is the biggest contributor to rollover crashes (45 percent). Table 35 identifies speed-related factors associated with the onset of rollovers. This greatly exceeds the 23 percent of all large-truck accidents attributed to "traveling too fast for conditions" for all large-truck crashes (FMCSA, 2006). Since large trucks have a high center of gravity, vehicle speeds required to initiate rollover on a curve are quite low. Further, large trucks operate chiefly on interstates and other high-speed roadways. As with speed-related incidents in general, it is not the very high speeds associated with "reckless" driving, but rather speed that exceeds what is safe for the particular combination of vehicles and roads.

Table 35. Causal Factors Related to Speed Occurring During Rollover Crashes Involving Drivers of All Large Trucks Sorted by Frequency of Occurrence

Rollover Factor Related to Speed	Frequency of Occurrence	Rollovers Related to Speed (%)	Rollovers Reviewed in LTCCS, %(N=242)
Misjudged the speed at which the curve could be taken	71	42	29
Not adjusting speed to load (stability, weight, or height)	30	18	12
In a hurry and disregarded speed limitation	17	10	7
Not adjusting speed to known bad brakes	15	9	6
Not adjusting speed to road conditions (slippery surface, grade)	12	7	5
Not adjusting speed to sharp turn at intersection	9	5	4
Did not notice sign or other speed-limiting information	5	3	2
Not adjusting speed to vehicles ahead	4	2	2
Aggressiveness toward other road users	3	2	1
Not adjusting speed to worn tire tread	3	2	1
Not adjusting speed to limited sight distance	2	1	<1
Total	**171**	**100**	

Source: LTCCS 2001–2003 data.

Curves

It is in handling curves that excess speed becomes the biggest factor, accounting for 71 rollovers, which is more than two-thirds of all those that are speed-related. Trucks with tractors appear the most vulnerable to curves. Straight trucks or single-unit trucks, which make up 24 percent of the all trucks involved in rollovers (see Table 29), have 33 percent of their crashes on curves, compared to 46 percent on curves for trucks with tractors (see Table 31). This reflects the relatively lower roll stability of the trailer.

Because the reasons drivers exceeded safe speeds on curves differ substantially, they are further subcategorized. The single biggest cause is simply misjudging the speed at which the curve can be safely entered. The single biggest rollover sources are the off-ramps of interstates and other high-speed highways where drivers carry too much speed onto the ramp. In some cases, it is the centripetal force that causes the truck to roll; in others, the truck drifts off the paved surface with a tire or the tires catch a structure or soft surface. In slightly more than half the cases, one or more other errors contributed to the rollover.

Loads

Thirty rollovers were the result of loads that were too heavy, insecurely fastened, or mounted too high in the truck. The effect of loads is evident in the fact that they have twice the effect on rollovers as other truck crashes. The effect of a cargo improperly loaded is experienced most often on curves, where the combination of speed and rate of turn creates a centripetal force sufficient to roll the truck over. However, some occurred in a lane change, with a wheel dropping off the pavement or with a cargo shift unrelated to the motion of the truck. In 18 cases, the overloads were combined with misjudgment of safe speed; had the driver either prevented the overload or reduced speed accordingly, the rollover might not have occurred.

Brakes

In 15 cases, the condition of the brakes prevented slowing down enough to avoid the rollover. The cases were fairly equally divided among curves, intersections, and steep downgrades. In four instances, bad brakes combined with misjudgment of maximum safe speed resulted in rollovers on curves. In all of these instances, the truck had been driven long and far enough for the drivers to be aware of the problem and to have accommodated for it by reducing speed. The drivers' failure to slow down is just as much a cause as the bad brakes.

Roads

Features of the road contributing to 12 rollovers were slippery surfaces (6), long downgrades (5), and a construction area (1). In all cases, the driver was aware of the safety threat posed and could have prevented the rollover situation by reducing speed, either by downshifting before starting downgrades or by earlier braking on slippery surfaces. As noted earlier, since nothing could be reasonably done to alter the condition of the road itself, it is not considered a cause.

Intersections

The nine intersection rollovers were a result of going too fast to make turns when trying to beat a traffic light, when unexpectedly encountering a T-intersection, or when making a last-second turn at a cross road (where a better choice would have been to keep going and then come back).

Vehicles

Four rollovers occurred when drivers failed to realize early enough that vehicles ahead had slowed and they were unable to stop in time. The primary cause was inattention, with one case due to insufficient following distance.

Tires

Three rollovers involved failure of the driver to adjust speed to account for worn tire tread, two in curves and one on a slippery surface.

Sight Distance

On two occasions, trucks approached the top of a hill and failed to reduce speed to accommodate for the limited sight distance. Upon seeing stalled traffic, they swerved sharply and rolled over.

7.4.2. Fatigue, Attention, and Distraction

Second to speed as a contributor to rollovers is the category including fatigue, attention, and distraction. Sixty-one instances were the result of these issues, as listed in Table 36.

Table 36. Causal Factors Related to Fatigue, Attention, and Distraction Occurring During Rollover Crashes Involving Drivers of All Large Trucks

Rollover Factor	Frequency of Occurrence	Rollovers Related to Attention (%)	Rollovers Reviewed in LTCCS, % (N=242)
Not paying attention ahead or to other danger source	26	43	11
Being asleep or drowsy enough to be unaware	22	36	9
Driver distracted (passengers, phones, sounds, etc.)	13	21	5
Total	**61**	**100**	

Source: LTCCS 2001–2003 data.

Inattention

The leading attention problem, inattention (in 26 rollovers), was simply not being observant in regard to what was going on ahead of the truck. This necessitated a sudden change in direction, leading to a rollover. In 12 of the cases, lack of attention was the only cause reported. The 11 percent of rollovers resulting from inattention is close to the 8.5 percent reported for all large-truck crashes. However, this is a smaller degree of involvement than that which occurs with motor vehicles in general. This is a finding less likely to be attributable to the alertness of those who drive large trucks than to the reduced attention demands of driving primarily on open highways outside of city and suburban traffic.

Sleep

Sleep is the second most frequent source of attention loss (22 of 61 cases). Falling asleep at the wheel, or at least becoming sufficiently drowsy to make the driver unaware of what was happening, accounts for this inattention. In some cases, it could be attributed to the time of day (early morning) or length of time without sleep, but the source was difficult to pin down in most cases. The most frequent result was drifting off the road and overturning; however, in six instances, the driver suddenly became aware of having left the road, attempted to steer back on, and rolled over on the road.

Distraction

The remaining attention problem is distraction, with 13 cases (5.4 percent). This is not far below the 8.5 percent involvement for all large trucks. The most common distractions were passengers—talking to or looking at them. Others included cell phones, CBs, tuning the radio, and hearing a strange sound. There were a few additional cases in which drivers reported a distraction, but the rollover cause lay elsewhere.

7.4.3. Control

Errors in controlling the motions of the truck were a factor in 47 rollovers, as shown in Table 37 (overcorrecting, improper steering, and improper braking). Of the responses needed to control the truck, steering was the most prone to errors, resulting in rollovers. Although failure to steer in a way that would keep the truck on the road was a frequent problem, an equal contributor to rollovers was overcorrecting (going one direction and quickly turning in the other direction). Maintaining adequate following distance, downshifting, and braking were smaller problems.

Table 37. Causal Factors Related to Control Occurring During Rollover Crashes Involving Drivers of All Large Trucks

Rollover Factor	Frequency of Occurrence	Rollovers Related to Control (%)	Rollovers Reviewed in LTCCS, % (N=242)
Overcorrecting after an error (offroad, wrong lane)	24	36	10
Lack of proper steering (over-/understeering)	19	29	8
Failure to keep adequate distance from vehicle ahead	9	14	4
Responding to vehicles/road incorrectly	7	11	3
Improper braking (e.g., locked brakes)	4	6	2
Failure to downshift for speed control	3	4	1
Total	**66**	**100**	

Source: LTCCS 2001–2003 data.

Steering

Poor steering control, including understeering or oversteering control, led to 19 rollovers. About half of these cases involved simple oversteering during lane changes and swerving more sharply than necessary to avoid trouble. Most of the remainder involved marginal steering control with difficulty staying in the lane, and two occurred in turning corners.

Overcorrection

Nineteen rollovers were the result of steering corrections—that is, turns in one direction followed by corrective turns that exceeded the stability of the truck. Situations leading to and coupled with overcorrection were falling asleep, inattention, steering errors, and distractions.

Following Distance

Nine rollovers occurred when trucks were overtaking the vehicles ahead of them. The vehicle was forced to turn sharply and rolled over. Had the truck been following at a reasonable distance, there would have been enough space to stop or make a gradual lane change. In three of these cases, better steering control might have prevented the rollover.

Maneuvering

In seven cases, the truck driver chose a maneuver that was inappropriate based upon faulty perception, false assumption, or just a poor decision.

Braking

Locking the brakes was considered a contributing factor in four rollovers in which some other error created the situation that led to the braking. In several other incidents, locked brakes were involved in loss of directional control and in long stopping distances. However, braking was not cited as a contributing factor, nor was it possible to tell whether the rollover might have been prevented with better brake application.

Downshifting

While going down long or steep hills, three drivers failed to put the truck in low gear and were unable to control speed by brakes alone.

7.4.4. Visual Search

Lack of adequate visual search (i.e., not looking in the right place at the right time), contributed to nine rollovers, as shown in Table 38 (some 3 percent of the total population of rollover crash causes, per Table 34). It should be noted that search-related factors occurred infrequently within the sample of rollover cases reviewed. However, it appears that visual search is less often a factor during rollover crashes than it is for all other crash types (nonrollovers) involving CMVs. Lack of adequate search was associated with 13 percent of the 1,090 crashes within the LTCCS dataset as reported by FMCSA (2006). This difference is due to the fact that most rollovers occur on interstates and other major highways where travel speeds are higher.

Table 38. Causal Factors Related to Visual Search During Rollover Crashes Involving Drivers of All Large Trucks

Rollover Factor	Frequency of Occurrence	Rollovers Related to Search (%)	Rollovers Reviewed in LTCCS, % (N=242)
Not looking to the side at intersection, lane changes	7	78	3
Not looking far enough ahead, roadside	2	22	<1
Total	**9**	**100**	

Source: LTCCS 2001–2003 data.

Search to the Side

Seven rollovers involving failure to search to the side were divided equally between initiating lane changes and crossing intersections. In one additional case, a driver turned across a railroad track where flashing lights signaled an approaching train. He assumed it was delivering to a local service area and did not look closely enough to judge its speed.

Search Ahead

The two situations involving failure to look far enough ahead involved one in which the driver's attention was diverted to the rearview mirror and one in which the driver was focused on the road directly in front of the truck. In most cases, the failures to respond to threats in the path ahead were the result of attention lapses rather than inadequate search.

7.4.5. Preoperation

Table 39 describes two categories of rollover resulting from conditions that existed at the time the truck took the road (i.e., the way the truck was loaded and the driver's mental and physical condition).

Table 39. Causal Factors Related to Preoperation During Rollover Crashes Involving Drivers of All Large Trucks

Rollover Factor	Frequency	Rollovers Related to Preoperation (%)	Rollovers Reviewed in LTCCS, % (N=242)
Height or security of load driver's responsibility	16	73	7
Mental or physical condition of driver causes rollover	6	27	2
Total	**22**	**100**	

Source: LTCCS 2001–2003 data.

Loading

In 16 of the rollovers caused by failure to adjust speed in curves to the load, the problem could have been avoided by better securing the load. Had the load not been allowed to shift, the truck would have remained upright, and in these instances, it was the driver's responsibility to make sure the load was properly secured before starting out. In the remaining instances the problem lay in the height, weight, or nature of the load itself (e.g., fluids), and reducing speed would have been the only preventive measure.

Driver State

Six rollovers occurred when drivers lost consciousness due to a physical ailment or the medication used to treat it. One instance of falling asleep appears to have been the result of medication. All of these were not new conditions and might not have become a rollover cause had drivers taken steps to prevent their occurring when they were behind the wheel.

7.4.6. Other Drivers

In all of the rollovers that have been described up to this point, the incident could be attributed to some mistake on the part of the person operating the truck. There were, however, 37 rollovers that were the fault of another driver, as shown in Table 40.

Table 40. Other Causal Factors Occurring During Rollover Crashes Involving Drivers of All Large Trucks

Rollover Factor	Frequency	Rollovers Related to Other Drivers (%)	Rollovers Reviewed in LTCCS, % (N=242)
Struck by another driver	33	89	14
Caused by another driver	4	11	2
Total	**37**	**100**	

Source: LTCCS 2001–2003 data.

Struck By

Of all the rollovers, 33 resulted from the truck being struck by another vehicle. The incidents included oncoming or passing vehicles turning into the truck's lane, and vehicles coming from the side at crossroads and entrances. In none of these cases could the truck driver have been reasonably expected to avoid being hit.

Caused By

In four cases, the truck was not struck but rolled over in the process of avoiding a collision with another vehicle. The situations were largely the same as those in which the truck was struck, and, again, the truck driver could not have prevented the rollover.

7.4.7. Vehicle

Table 41 shows the frequency of vehicle-related rollover causes. The four factors are described below.

Table 41. Causal Factors Related to the Vehicle Occurring During Rollover Crashes Involving Drivers of All Large Trucks

Rollover Factor	Frequency	Rollovers Related to Vehicle (%)	Rollovers Reviewed in LTCCS, % (N=242)
Caused by poor tread and blowout	5	39	2
Vehicle load insecure or too high	4	31	2
Caused by sudden brake failure	2	15	<1
Part failure unable to be anticipated/controlled by driver	2	15	<1
Total	**13**	**100**	

Source: LTCCS 2001–2003 data.

Tire Failure

In addition to the three rollovers due to speed and worn tires (Table 35), five were the result of blowouts that did not involve any visible defects in the tire that would have caused tire failure to be anticipated by drivers.

Loads

Of the rollovers resulting from the way the truck was loaded, four cases involved trucks that were loaded prior to the drivers being assigned to them. Therefore, the load could be considered part of the vehicle.

Brake Failure

Two rollovers occurred when brakes suddenly failed on long downgrades. In neither case did the driver have reason to suspect a problem and possibly shift to a lower gear before beginning the descent.

Part Failure

Two rollovers were caused by part failures, one in the steering mechanism and one in a rear axle.

8. CONCLUSIONS

The overall goal of this study was to identify and evaluate promising technologies designed to increase safety belt use by CMV drivers. In total, 13 technologies were identified and classified in three category types as follows:

Reminder Systems:

1. Dash Warning Light/Telltale (Passive System)
2. Intermittent Dash Warning Light/Telltale (Active System)
3. Audible Reminder (Passive System)
4. Enhanced Audible Reminder (Active System)
5. Transmission Interlock System

Comfort Strategies:

1. Safety Belt Tension Adjustors
2. D-Ring Height Adjustors
3. Seat-Integrated Safety Restraint System
4. Safety Belt Covers

Enforcement Strategies:

1. Brightly Colored Safety Belts
2. Onboard Data Recorders
3. Exterior Safety Belt Use Indicator
4. Driver Monitoring Stickers

These technologies were identified through a review of existing scientific literature and through interactions with industry sources. Stakeholder information helped the research team to gain insight into strengths and weaknesses of each approach and provided insight regarding the most promising systems. Unintended consequences of each device were considered and alternative systems were explored during the stakeholder discussions. A BCA was performed considering the tradeoff between estimated aftermarket costs for each promising system and the anticipated reductions in injury with increased safety belt wearing if each device was introduced. Overall technology results were presented in Chapter 6.

Promising Safety Belt Technologies: Based on information provided by industry stakeholders and drivers, the four most promising systems were: (1) Enhanced Audible Reminder System, (2) Brightly Colored Safety Belt System, (3) Safety Belt Tension Adjustor, and (4) Seat-Integrated Safety Restraint System.

Enhanced Audible Reminder Systems appear to be the most promising technology based on research performed here. The technology is well understood and is readily available for integration into CMVs as needed. These systems are widely available today in passenger vehicles. Further, the systems do not require additional enforcement or management activities in order to increase safety belt use. For this reason, these devices would be equally effective in all types of carrier operations. It is important to note that, for vehicles with a GVWR of 10,001 lbs or more, no visual or audible safety belt reminders are required by NHTSA's Federal Motor Vehicle Safety Standards. Conversely, NHTSA has required safety belt reminder systems in passenger vehicles since 1974.

Brightly colored safety belts were also found to be a promising technology to improve the rate of safety belt use by drivers of large trucks. The strategy facilitates enforcement of existing safety-belt-use laws by safety officials and law enforcement as well as enforcement of corporate policies by fleet safety managers. The technology is the least expensive device of those considered most promising during this study. Currently, a growing number of fleet owners are voluntarily choosing to equip their vehicles with these safety belts. The systems provide some visual cues to drivers so that they buckle up, yet they rely primarily on the perceived threat of enforcement in order to be effective. In addition, installation of these systems in fleet vehicles provides drivers with a clear indication of a company's commitment to their drivers' safety. At this time, little is known about the relative effectiveness of brightly colored safety belts in increasing safety belt use by CMV drivers; however, preliminary indications by fleet safety managers have suggested considerable increases in safety belt use rates when they are available in the vehicle. This increase relies somewhat on the implementation of a concurrent driver education program and rigorous enforcement of corporate safety guidelines requiring driver safety belt use once the brightly colored belts are installed.

The third technology identified was the safety belt tension adjustor, commonly known as the Komfort Latch. This device, when used correctly, can aid drivers in configuring safety belt systems for optimized comfort. The technology is currently factory-installed by the vehicle manufacturer in close to 90 percent of new Class 8 vehicles sold in the United States according to restraint manufacturer information. The deployment of this strategy in a vehicle or fleet of vehicles must be accompanied by driver education regarding the proper use of the systems and regarding the value of safety belt wearing in preventing serious injuries or death during crashes.

The Komfort Latch adds a variable amount of slack to the safety belt system in order improve driver comfort. The amount of slack that is added can be selected by the driver. The ability to add slack may increase belt wearing rates due to improvements in safety belt comfort; however, the injury-reducing effectiveness of the safety belt system may be reduced with added slack in the event of a crash.

The final device considered promising is the seat-integrated safety restraint system. This technology was favored by vehicle manufacturers in particular. These systems have safety belt anchorages integrated into the seat structure so that relative motion between a suspended seat and a fixed safety belt is eliminated or reduced significantly. This technology is expensive and not yet ready for deployment; however, in the future, these systems could help to alleviate comfort concerns by drivers without degrading restraint system performance. Implementation of such a system would require extensive field evaluation to confirm that the devices do improve comfort overall. Further, crashworthiness evaluations should be conducted to determine if the addition of such a system does not degrade the protection of occupants during high-severity frontal crashes or during other common crash scenarios involving trucks.

Vehicle manufacturers have indicated that implementation of the enhanced audible reminder systems, brightly colored safety belts, or safety belt tension adjustors do not pose a technical challenge, yet these systems will not be implemented without sufficient market demand or pressure due to regulatory requirements. Seat-integrated safety restraints, however, would require significant resources before implementation, including some vehicle redesign and safety testing to verify their performance.

Cost Benefit Analysis: A detailed cost benefit analysis was performed to estimate injury cost savings likely as safety-belt-wearing rates for drivers of large trucks increased. This cost savings was then compared with likely costs for each of the four most promising systems. Results of this analysis were presented in Chapter 6.

The cost analysis was performed for drivers of all large trucks/CMVs and for drivers of Class 7 and 8 vehicles specifically considering frequency and average injury costs for belted versus unbelted driver populations. Overall, the review indicated that $675 million could be saved annually if all unbelted drivers of large trucks were wearing safety belts during their crashes. For Class 7 and 8 drivers alone, $489 million in injury and fatality costs could be saved. The BCR for the least expensive technology option (i.e., brightly colored safety belts) was 1.7 for all large trucks and 4.5 for Class 7 and 8 trucks. This ratio suggests that for every dollar spent equipping vehicles with brightly colored safety belt systems, a return of $1.70 in injury costs savings can be expected due to increased safety belt use for all trucks. For Class 7 and 8 trucks, a return of $4.50 is expected for every dollar spent equipping trucks with the devices. This calculation assumes that brightly colored safety belts would lead to a 10 percent increase in safety-belt-wearing rates of drivers of all large trucks. The BCR for the enhanced audible reminder system was 2.6 for all trucks and 6.9 for Class 7 and 8 trucks, assuming that the devices are 15 percent effective in increasing safety belt use rates. The safety belt tension adjusters had a BCR of 0.73 for all large trucks and 1.93 for Class 7 and 8 trucks. This assumes that the device would to lead to a 5-percent increase in safety belt use. Finally, the seat-integrated restraint system, assumed to increase safety belt wearing rates by 5 percent, had a BCR of 0.26 for all trucks and 0.69 for Class 7 and 8 trucks alone. Overall, this BCR indicates that investing in seat-integrated restraint systems is not cost-beneficial at current device costs ($970/seat) if the anticipated increase in safety-belt-wearing rate is only 5 percent. If other concurrent improvements are realized by the introduction of these devices, the BCR would further improve.

The BCA relies on estimates of device effectiveness. For these calculations, effectiveness values used were based on industry stakeholder estimates and estimates of the research team. Additional analyses are required to determine the exact changes in safety-belt-use behavior that would result from widespread deployment of each device. Some devices, like the safety belt tension adjustor, require driver instruction before any change in wearing rates would occur, as these devices are already widely available to drivers. A more detailed cost-based analysis, taking into account the cost of training, may be appropriate. The training curriculum could be developed by fleet safety personnel, or a standardized safety training course could be developed and disseminated by FMCSA or other interested parties.

Crash Data Analysis: Crash data analysis results provide an overview of unbelted and belted populations of drivers of all large trucks who are fatally injured. The analysis shows that the majority of drivers of large trucks who die during crashes are unbelted (59 percent in 2005, for cases in which safety belt use was known). The most frequent crash types resulting in driver fatality are rollover crashes and vehicle-to-vehicle collisions. In terms of driver fatality per crash involvement, rollover crashes were found to have the highest rate, with 2.7 percent fatalities per crash involvement, followed by noncollision events with a fatality rate of 0.78 percent fatalities per crash involvement. Noncollision events include vehicle jackknife, ejections without impacts, and vehicle fires. During collisions with fixed objects, 0.65 percent fatalities per crash involvement were found. Collisions with fixed objects include impacts with roadside features including narrow objects, roadside devices like guardrails, and other fixed devices.

Overall, 83 percent of fatal crashes occur on high-speed roadways during daytime normal driving conditions. Detailed clinical case reviews were conducted using the LTCCS to characterize crashes in which belted occupants died. The analysis suggests that belted occupants were primarily injured during crashes where significant structural intrusion occurred. Clinical case reviews were conducted using the LTCCS data due to the availability of detailed damage information within the file and detailed information describing driver injury profiles. During the review, no evidence of safety-belt-induced injury was found for any cases considered.

A subsequent review of unbelted-driver crash cases was conducted using the LTCCS database to determine what impact safety belt use would have had on driver injury outcomes had drivers buckled up. Overall, this review identified that the number of moderately to seriously injured drivers would have been reduced by 47 percent to 75 percent overall. This corresponds with a potential reduction of 1,600 to 2,500 moderately to seriously injured drivers per year. The review also identified that 39 percent of fatalities (in the population considered) might have been prevented if a traditional three-point safety belt had been worn during the crash events. This corresponds with the prevention of 138 driver deaths per year if all unbelted CMV drivers had used their safety belts. If safety belt use rates rose to the level observed for passenger vehicle drivers in 2006 (from 59 percent to 81 percent), a total of 74 CMV driver fatalities would be prevented. Similarly, if a 22-percent increase in CMV driver safety belt use rates occurred, approximately 860 to 1,340 moderately to seriously injured CMV drivers would have sustained fewer serious injuries or no injuries at all during their crashes.

8.1. SUMMARY

The goal of this study was to assist FMCSA in identifying promising technologies to increase safety belt use by CMV drivers. Each technology explored could be classified in one of three categories: (1) comfort strategies, (2) reminder strategies, or (3) enforcement strategies. A second phase of the study involved the analysis of real-world crash data from the FARS and LTCCS databases to identify characteristics of fatal and serious-injury crashes involving CMV drivers. The analysis considered common characteristics of belted and nonbelted drivers of all large trucks. For this study, the terms “all large trucks” and “Commercial Motor Vehicles” (CMVs) are used interchangeably and refer to any vehicle with a GVWR of 10,001 pounds or more.

This study identified four promising technologies likely to increase safety belt use by CMV drivers. These are: (1) Enhanced Audible Reminder Systems, (2) Brightly Colored Safety Belts, (3) Safety Belt Tension Adjustors, and (4) Seat-Integrated Safety Restraint Systems. These technologies provide audible and visual reminders for drivers to buckle up, or improve the comfort of existing safety belt systems to address complaints made by some drivers.

During the study, currently available technologies were identified during a systematic review of technical publications and other available information sources. Discussions with industry stakeholders, including vehicle and restraint manufacturers, trade organization representatives, insurance and safety researchers, and CMV drivers, were conducted to better understand their perspectives on the safety-belt-use problem and to determine their opinions of each technology considered. The research team attended several meetings of FMCSA's CMV Safety Belt Partnership to discuss the research and explore viable solutions. Many of the partnership members also contributed significantly during stakeholder discussions. A BCA was performed to estimate the potential injury and fatality cost savings likely if a fleet owner or vehicle owner chose to equip their vehicles with any of the devices in question.

The study concludes that increased safety belt use would significantly reduce the number of seriously and fatally injured CMV drivers. The economic burden associated with these casualties due to nonuse of safety belts for drivers of all large trucks is estimated to be $675 million annually. This cost of unbelted driver injuries and fatalities is $489 million annually for Class 7 and 8 truck drivers alone. Study results indicate that if a device increases safety belt use by at least 15 percent and the device cost is $273 or less per vehicle, the device is considered to be cost-beneficial. For Class 7 and 8 trucks alone, if the device costs less than $725 per vehicle and is expected to increase safety belt use by 15 percent, the system is cost-beneficial. Most of the technologies considered during the study were significantly less expensive than $725 and would therefore be cost-beneficial solutions to increase safety belt use in Class 7 and 8 trucks. If a device increases safety belt use as little as 5 percent, then a device that costs as much as $91 for all large trucks or $240 for Class 7 and 8 trucks would be cost-beneficial.

The introduction of basic audible or visual reminder systems might positively affect safety belt use rates of CMV drivers; however, it was discovered that the implementation of enhanced audible reminder systems would likely bring about the greatest positive change. This is based on evidence of their successful use in passenger vehicles and on feedback from industry stakeholders and drivers. During this study, it was discovered that no Federal regulations exist that require safety belt reminder systems of any kind (audible or visual) for vehicles weighing 10,001 pounds and more. This differs from passenger vehicle standards, where audible and visual reminders are required for drivers.

The introduction of a brightly colored safety belt system is another cost-effective and promising approach to increase safety belt use rates by CMV drivers. A safety belt system with enhanced visibility allows for simplified enforcement of safety-belt-use laws and corporate safety-belt-use policies. Perhaps more important, the presence of a brightly colored safety belt increases the perceived threat of enforcement. Based on estimates performed here, enhanced audible reminders and brightly colored safety belts are both assumed to be cost-beneficial solutions. Their anticipated BCRs are 2.60 and 1.70, respectively, for all large trucks. If the BCR is greater than 1 for a particular device, it can be considered to be a cost-beneficial solution where the predicted injury cost savings due to increased safety belt use exceeds the cost required to equip one or more vehicles with the device. For drivers of Class 7 and 8 trucks alone, the BCRs for enhanced audible reminders and brightly colored safety belts are 6.90 and 4.50, respectively.

Safety belt tension adjustors, commonly known as the Komfort Latch, are widely available today and are designed to help CMV drivers configure safety belt systems for optimal comfort. However, specialized driver education in the proper use of the systems must occur in order to realize the greatest increase in safety-belt-wearing rates. In addition, the Komfort Latch System allows for the introduction of a variable amount of slack into the safety belt system to achieve a more comfortable fit. The introduction of slack into a safety belt is known to reduce its effectiveness in preventing injuries and fatalities. Seat-integrated safety restraints also offer an enhanced comfort solution, yet device costs exceed the likely benefit of the proposed system based on calculations performed here.

Some approaches suggested here must be adopted voluntarily by vehicle manufacturers or fleet owners when purchasing vehicles. Others could be addressed through improvements in existing safety belt regulations.

The data analysis tasks performed here identified key factors of the belted and unbelted CMV driver population. For both belted and unbelted drivers, the majority of CMV driver fatalities occurred during rollover crashes, followed by impacts with other vehicles. A review of belted-driver fatalities and serious-injury crashes indicated that virtually all involved significant damage to the occupant compartment. The most common crash types in which a belted driver died were rollovers with considerable roof or side structure damage. Impacts with fixed objects, including roadside objects like bridge abutments and trees, occur frequently during fatal crashes.

Overall, increased safety belt use by drivers of large trucks would reduce the frequency and severity of driver injuries and fatalities. Based on a review of unbelted driver fatalities, it was estimated that 39 percent of fatalities (approximately 138 drivers per year) could be prevented with safety belt use. If safety belt use rates rose to the level observed for passenger vehicle drivers in 2006 (from 59 percent to 81 percent), a total of 74 CMV driver fatalities would be prevented. The review also suggests that 47 to 71 percent of moderately to seriously injured drivers (1,600 to 2,500 drivers per year) could have sustained injuries less severe if they were properly restrained. This corresponds to preventing moderate to severe injuries in approximately 860 to 1,340 CMV drivers if safety belt use rates rose to the level observed in 2006 for passenger vehicle drivers.

REFERENCES

Balci, R., Vertiz, A., and Shen, W. (2001.) Comfort and Usability of the Seatbelt (SAE Technical Paper No. 2001-01-0051). Washington, DC: Society of Automotive Engineers.

Bentley, J. J., Kurrus, R., and Beuse, N. (June 2003.) Qualitative research regarding attitudes towards four technologies aimed at increasing safety belt use (Docket Number NHTSA–2002–13226). Washington, DC: U.S. Department of Transportation, National Highway Traffic Safety Administration.

Bergoffen, G. Knipling, R. R., Tidwell, S.A., Short, J.B., Krueger, G. P., Inderbitzen, R.E., Reagle, G., Murray, D.C. (2005). Commercial Truck and Bus Safety Synthesis Program, Synthesis 8, Commercial Motor Vehicle Driver Safety Belt Usage. Transportation Research Board.

Eby, D.W., Molnar, L.J., Kostyniuk, L.P., Shope, J.T. (2005). Developing an Effective and Acceptable Safety Belt Reminder System. Proceedings of the Nineteenth International Technical Conference on the Enhanced Safety of Vehicles, Paper No. 05-0171.

Federal Register. (1974). Federal Motor Vehicle Safety Standards: Seat Belt Warning System. Vol. 39, No. 236, Dec. 6, pp. 42,692–42,693.

Fildes, B., Fitzharris, M., Koppel, S., and Vulcan, P. (2002). Benefits of Seat Belt Reminder Systems. Report CR 211. Monash University Accident Research Centre, Victoria, Australia, Dec.

FMCSA. Report to Congress on the Large Truck Crash Causation Study, U.S. Federal Motor Carriers Safety Administration, Report Number MC-R/MC-RRA, 109th Cong., 2nd sess., March 2006.

Hayworth, N.L., Bowland, L., Foddy, B., Elliot, B. (1996). Truck Seat Belts. Proceedings of the Fifteenth International Technical Conference on Enhanced Safety of Vehicles.

Howell, W., Champion, D.A., DeLucia, P.R., Bella Dinh-Zarr, T., Finkelstein, M.M., Haseltine, P.W., Loeb, P.D., Reinfurt, D.W., Tanur, J.M., Viano, D.C., Williams, A.F. and Zmud, J.P. (2003). Special Report 278: Buckling Up: Technologies to Increase Seat Belt Use. Transportation Research Board, National Academies, Washington, DC. Available from *http://onlinepubs.trb.org/onlinepubs/sr/sr278sum.pdf*.

Robertson, L. S. (1975). Safety Belt Use in Automobiles with Starter-Interlock and Buzzer-Light Reminder Systems. *American Journal of Public Health*, *Vol. 65*, No. 12, pp. 1319–1325.

Simon, M.C., Botto, P., Page, P., Paulhet, F. (2001). The Potential Gain to be Achieved by Generalization of Seat Belts and Airbags in Trucks, The International Conference on Enhanced Safety of Vehicles, SAE 2001-06-0193, Amsterdam, Holland.

Zaloshnja E., Miller T.R., Romano E.O., Spicer R.S. (2004.) Crash Costs By Body Part Injured, Fracture Involvement, and Threat-To-Life Severity, United States, 2000. *Accident Analysis and Prevention 36* (3):415–427.