TRANSPORTATION RESEARCH
CIRCULAR
Number E-C117 May 2007

The Domain of Truck and Bus Safety Research

TRANSPORTATION RESEARCH BOARD
OF THE NATIONAL ACADEMIES

TRANSPORTATION RESEARCH CIRCULAR E-C117

The Domain of Truck and Bus Safety Research

Transportation Research Board
Truck and Bus Safety Committee

May 2007

Transportation Research Board
500 Fifth Street, NW
Washington, DC 20001
www.TRB.org

TRANSPORTATION RESEARCH CIRCULAR E-C117
ISSN 0097-8515

Transportation Research Board
500 Fifth Street, NW
Washington, DC 20001
www.TRB.org

Jennifer Correro, Proofreader and Layout; Ann E. Petty, Production Editor

Contents

Acknowledgments

This Transportation Research Board Circular was developed by the members of the TRB Truck and Bus Safety Committee (ANB70). The Circular was conceived, planned, and written voluntarily by the committee members and friends. As in most such successful endeavors, there was a champion providing leadership and intellectual stimulation, and doing extensive behind-the-scenes work. Ronald Knipling was that champion, and his several years of quiet, persistent, patient hard work made this committee initiative a reality. During most of that time, he was the committee chair. Our sincerest thanks go to Ron and to each of the authors and coauthors for creating this extraordinary document.

Joel Ticatch
Chair, Truck and Bus Safety Committee

Richard Pain
TRB Staff Representative to the Committee

Introduction

RONALD R. KNIPLING

This Transportation Research Board (TRB) Circular was written by the members and friends of the TRB Truck and Bus Safety Committee (ANB70). The committee was founded in 2003. Organizations that were precursors to the committee included a Truck and Bus Safety Subcommittee of the Safety Management Committee (formerly A3B15, now ANB70) and a Truck and Bus Safety Task Force (A3B57), which championed the transition from subcommittee to full committee status.

Like other TRB committees, the Truck and Bus Safety Committee consists of professionals committed to advancing their disciplines and improving the North American transportation system. The committee's goal is to "focus on motor carrier safety in all its aspects; to include research and evaluation in human, roadway, vehicle, operational, and organizational arenas as they relate to motor carrier safety."

The broad purpose of this document is to explore and articulate essential information and perspectives on truck and bus safety research and, in so doing, establish a knowledge base and charter for the new committee. Some of the areas explored may become principal topics of future ANB70 subcommittees or other initiatives. The committee believes that the publication of this circular will energize its members, attract new participants, and serve the greater truck and bus safety community. That community includes the U.S. Department of Transportation (DOT) and other federal agencies, state DOTs and other agencies, academic researchers, truck and bus industry trade associations, and of course truck and bus companies, managers, and drivers.

Truck and bus safety research is multidisciplinary and encompasses a number of perspectives and disciplines. It shares with the broader topic of traffic safety a concern with human, vehicular, and environmental (i.e., roadway) factors in motor vehicle crashes. Unlike motor transportation in general, however, commercial motor transportation safety is significantly influenced by industry operational requirements, types of operations to meet those requirements, carrier safety management policies and activities, legal and regulatory mandates and restrictions, and multi-faceted enforcement activities.

Reflecting the multidisciplinary nature of truck and bus safety and the range of ANB70 committee and member interests, this circular addresses eight major topics, as follows:

1. Problem assessment and data,
2. Laws and regulations,
3. Enforcement and compliance,
4. Driver health and wellness,
5. Driver human factors,
6. Carrier safety management,
7. Vehicle design and technology, and
8. Roadway design and operations.

Each of the above chapters is organized in a topical fashion with five to 10 prominent topics addressed within each chapter. These do not represent all of the topics that might be addressed under each chapter heading, but rather the ones chapter authors selected as most important or best understood. Each chapter closes with a discussion of research and development (R&D) needs relating to each area. R&D is conceived broadly as the discovery of new knowledge and the creation and validation of new tools benefiting commercial motor vehicle (CMV) transport. Conclusions relating to outstanding R&D needs in each area are not presented as specific study recommendations to targeted organizations, but rather as needs that could potentially be addressed by various organizations using various methodologies.

The circular's eight chapters were written largely independently by different groups of authors and coauthors, working under the aegis of the committee. TRB and the Truck and Bus Safety Committee are most grateful for the time, information, and expertise contributed by each of the authors and coauthors of these chapters. Individual authors and coauthors are responsible for the content of each chapter, but the whole committee made an effort to provide information and suggestions to chapter authors, and to identify the essential facts of the many topics and issues addressed. Nevertheless, the views expressed in individual chapters are those of the chapter authors and do not necessarily represent those of the TRB or the Truck and Bus Safety Committee.

During the same time period in which this Circular was developed, TRB undertook a complementary effort in support of the Federal Motor Carrier Safety Administration (FMCSA) and truck and bus safety in general. The Conference on Future Truck and Bus Safety Research Opportunities brought together experts from industry, government, and academia to identify and consider emerging and future opportunities for high-potential truck and bus safety research. The conference was planned and coordinated by a committee of 12 distinguished traffic safety professionals, appointed by the National Research Council and supported by the TRB staff and consultants. The "futures" committee also developed consensus findings and 23 recommendations for priority R&D initiatives that might be undertaken by government and other R&D organizations. Topic areas addressed included

- Problem assessment;
- Human performance and behavior;
- Enforcement, compliance, and security management;
- Driver health and wellness;
- Workforce composition, skills, and training;
- Vehicle design and technology;
- Roadway design and operations; and
- Liability and acceptance of new technology.

Although there was no direct coordination between the development of this circular and the futures assessment, the topics addressed were similar and overlapping, as seen above. Many of the recommendations of the futures report address research needs identified in this Circular. The committee recognizes the affinities between the two efforts and commends the futures report to the reader (TRB, 2006).

IMPORTANCE OF TRUCK AND BUS TRANSPORT AND SAFETY

Commercial truck and bus transport have major economic importance in North America and in most of the developed world. In the United States, commercial trucking has annual revenues of more than $500 billion and employs nearly 10 million people. In 2002, 2.6 million Class 8 trucks and 3.5 million Class 3–7 trucks were used for business purposes in the United States [American Trucking Associations (ATA), 2004]. In 2003, 9.1 billion tons of freight were transported by intercity and local trucks, representing 69% of total domestic tonnage shipped (ATA, 2004). In the United States there are about 11 million commercial drivers license (CDL) holders, of whom 3.0 to 3.3 million are active truck drivers (FMCSA, 2004).

North American intercity and charter buses carry an estimated 860 million passengers annually, more than are transported by commercial air carriers or rail (Banks, 2000). Motorcoaches log nearly 30 billion passenger miles annually. During a 5-year period from 1997–2001, there were 219,000 total traffic fatalities in the United States, but only 56 were motor coach occupants (Carmondy, 2002).

The importance of CMV transportation to the North American economy has increased with the implementation of the North American Free Trade Agreement (NAFTA). Most cross-border freight travels by truck. In 2004, for example, the U.S.–Canadian truck border crossings totaled more than 96 million tons (87 billion kilograms) and more than US$125 billion in value (Can$163 billion, according to Statistics Canada international merchandise trade data).

A major factor impacting the entire CMV transport industry is the commercial driver shortage (Global Insight, 2005). The driver shortage limits the economic growth of the industry and also makes it virtually impossible for most truck and bus fleets to be highly selective in driver hiring. The current (2005) commercial driver shortage is approximately 20,000, but the shortage is expected to rise to more than 100,000 over the next decade as the principal commercial driver demographic group (white males aged 35–54) decrease in number (Global Insight, 2005). Overcoming the driver shortage will require the industry to hire a greater diversity of drivers as well as to take steps to make the occupation more attractive to potential drivers. The chronic and worsening driver shortage has direct, industrywide implications for safety as well as economic growth. The safety performance of commercial drivers varies (Knipling et al., 2004) just as performance in almost any profession or task varies among individuals. Some degree of industrywide hiring selectivity has been proposed to maximize the extent to which safer driver candidates are hired and less safe drivers are not.

Large trucks are associated with a significant portion of the overall U.S. traffic crash picture. Table 1 presents 2003 statistics on U.S. police-reported crashes based on NHTSA statistics from the Fatality Analysis Reporting System (FARS) and the General Estimates System (GES). For the purposes of these statistics, large trucks were defined as those trucks with gross vehicle weight ratings (GVWR) of greater than 10,000 lb, although the majority of these crashes involved trucks with GVWRs of greater than 26,000 lb.

TABLE 1 2003 Police-Reported Motor Vehicle Traffic Crashes

Crash Type	Crashes Involving Large Trucks	Large Truck %	All Crashes
Fatal	4,289	11.2%	38,252
Injury	85,000	4.4%	1,925,000
Property damage only	347,000	7.9%	4,365,000
Total	436,000	6.9%	6,328,000

Source: NHTSA (FARS and GES).

As seen in Table 1, the biggest percentage involving large trucks is in fatal crashes—they were involved in 11% of all 2003 fatal crashes. A total of 4,986 people were killed in these fatal crashes involving large trucks, which was 11.7% of the 42,643 total traffic crash fatalities for the year. Truck tractors pulling semitrailers (also known as combination-unit trucks) accounted for 75% of the large trucks involved in fatal crashes (FMCSA, 2005).

The economic impact of large truck and bus crashes is significant. Zaloshnja and Miller (2002) determined that police-reported crashes involving large trucks (greater than 10,000 lb) had an average cost of $59,153 in 2000 dollars. These costs included medical and emergency services, property damage, lost productivity, and a monetary valuation of pain, suffering, and quality-of-life loses associated with these crashes. The average cost of crashes involving transit or intercity buses was $32,548. For crashes with injuries, these costs rose to $164,730 for large trucks and $77,043 for buses. Annual total U.S. costs for large truck crashes averaged more than $19.6 billion for 1997–1999, whereas bus crashes averaged far less at $0.7 billion.

Wang, Knipling, and Blincoe (1999) estimated that average annual and lifetime crash costs (including all damage and injury to all involved parties) for individual combination-unit trucks are approximately five times greater than those for individual passenger cars or light trucks and vans. Single-unit truck annual and lifetime crash costs are only slightly greater than those of light vehicles. Mileage exposure differences are a predominant factor in these vehicle type differences; on a per-vehicle-mile-traveled (VMT) basis, crash costs are actually about the same for combination-unit trucks, single-unit trucks, and light vehicles.

RATES AND CHARACTERISTICS OF LARGE-TRUCK CRASHES

Fatal crash rates per 100 million VMT are higher for large trucks than for passenger vehicles, although the rates have converged somewhat in recent years. In 2003, the fatal crash rate for large trucks was 2.2 per 100 million VMT versus 1.8 per 100 million VMT for passenger vehicles (FMCSA, 2005). In contrast, injury crash rates are considerably lower for large trucks (41 per 100 million VMT in 2003) than for passenger vehicles (126 per 100 million VMT). Fatal and injury crash rates for large trucks have declined significantly over the past decade. From 1993 to 2003, for example, the fatal crash rate for large trucks declined by 20%, and the injury rate declined by 32%. Over the same years, the number of large-truck–related fatalities actually increased by 3%, reflecting a significant increase in total large-truck VMT over the period.

As noted, individual large trucks travel, on average, far more miles annually than do passenger vehicles. Greater mileage exposure means greater crash risk. In 2003, 4,669 (0.06%) of 7.9 million registered large trucks were involved in fatal crashes versus 48,237 (0.02%) of 217.0 million passenger vehicles (FMCSA, 2005). Contributing to this disparity are differences in average crash severity, reflective of large-truck size, weight, and body stiffness. Per the 2003 crash statistics in Table 1, about 1.0% of large-truck crashes result in a fatality (i.e., 4,289/436,000) versus about 0.6% of all vehicle crashes (i.e., 38,252/6,328,000). Using monetary cost measures of injuries and property damage, Wang, Knipling, and Blincoe (1999) found that crashes involving single-unit large trucks (i.e., straight trucks) were, on average, 78% more severe (as measured by "harm" metrics) than crashes involving all vehicle types combined, and crashes involving combination-unit trucks (tractor-semitrailers) were 120% more severe.

If there is a positive side to the above statistics, it is the fact that these differences in individual vehicle crash involvement likelihood and severity potentially mean that crash countermeasures may have greater benefits when applied to long-haul large trucks or their drivers than when applied to passenger vehicles or their drivers. Thus, long-haul large trucks are often the platform of choice for cost-effective implementation of advanced safety technologies or other vehicle-based crash countermeasures (Maccubbin, Staples, and Mercer, 2003; Wang, Knipling, and Blincoe, 1999).

The majority of fatalities associated with large truck crashes occur to persons outside the truck. These are mostly occupants of other vehicles (e.g., passenger cars and light trucks and vans), but also include nonoccupants such as pedestrians and bicyclists. Of the 4,986 fatalities that resulted from crashes involving large trucks in 2003, 78% were occupants of another vehicle, 8% were nonoccupants, and 14% were large-truck occupants (FMCSA, 2005).

Even though large truck occupants are not those most often hurt or killed in large truck crashes, commercial drivers face considerable occupational risk from traffic crashes and other accidents. In 2003, 620 drivers of large trucks were killed in traffic crashes (FMCSA, 2005). Commercial drivers in the United States experience more job-related fatalities and a higher rate per 100,000 employees than any other profession [Centers for Disease Control (CDC), 2004]. In part this is related to the high mileage exposure of long-haul trucks and drivers.

Obtaining valid crash and injury statistics for motor coaches is problematic because most state databases do not distinguish between intercity or charter and local transit buses. The American Bus Association website (www.buses.org/safety_data/statistics/) cites National Safety Council statistics for the years 1989 to 1998 showing that there were an average of 4.3 U.S. motor coach passenger fatalities per year while annual passenger miles averaged approximately 25 billion.

FACTORS IN COMMERCIAL VEHICLE CRASHES

Just as truck safety is multidisciplinary, understanding large-truck crashes requires a conceptualization of multiple interacting factors. Figure 1 (Knipling et al., 2004) is a conceptualization of major crash risk factors. At any given time, human, vehicular, and environmental influences and events conspire to affect crash risk. Crash causation studies consistently show, however, that vehicle and environmental factors are less significant than human factors. This is true for traffic crashes in general (Treat et al., 1979) and for large-truck crashes (Craft and Blower, 2004).

Human factors involved in large-truck crashes can be subdivided in various ways. The most common critical errors made by drivers, whether they are truck drivers or other involved drivers, appear to be recognition failures, e.g., failure to see the other vehicle in time to avoid the crash, often due to distraction or other inattention. Another major category is decision errors, including gap misjudgments and also unsafe behaviors such as tailgating or driving too fast for conditions. Other driver error categories include performance errors (failure to control vehicle properly) and critical nonperformance, which includes asleep-at-the-wheel and illness.

The “other driver” is clearly a major source of large truck crash risk. In an analysis of fatal crashes between large trucks and passenger vehicles, passenger vehicle driver errors or other driver factors were cited in more than two-thirds of these crashes, whereas truck driver errors were cited in less than one-third [FHWA Office of Motor Carriers (OMC), 1999; Blower, 1999]. In preliminary data on 287 two-vehicle crashes from the FMCSA–NHTSA Large Truck Crash

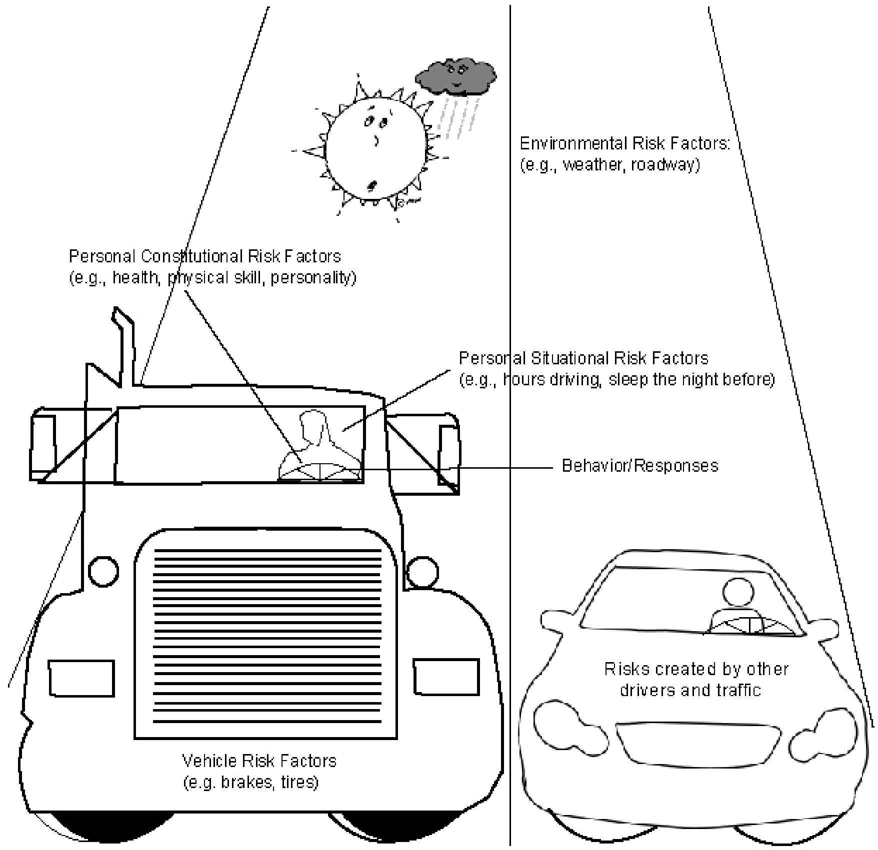

FIGURE 1 Interaction of factors affecting commercial driver crash involvement. (Source: Knipling et al., 2004.)

Causation Study (LTCCS), the "critical reason" for the crash was attributed to the other vehicle or driver in 70% and to the truck or truck driver in 30% (Craft and Blower, 2004). The critical reason does not necessarily connote "cause" or "fault" (Blower and Campbell, 2005) but it is typically the proximal driver error precipitating the crash.

Other studies have reported different attributions of error between truck and light vehicle drivers. Council et al. (2003) examined "fault" in 1994–1997 North Carolina police-reported truck–car crashes of all severity levels. Their findings for fatal crashes in the North Carolina sample were similar to those of Blower (1999), but when all police-reported severities were considered, truck drivers were assigned fault in more crashes (48%) than were car drivers (40%). Truck drivers had the highest fault percentages for backing and rear-end crashes. The car driver percentages were highest for head-on and angle crashes.

It appears that most truck–car crashes are precipitated by the same driver mistakes and misbehaviors that precipitate crashes in general. Kostyniuk, Streff, and Zakrajsek (2002) analyzed 1995–1998 fatal crashes and found that, on the whole, unsafe driving actions that lead to fatal car–truck crashes are equally likely to lead to fatal car–car crashes. Five driver factors (failing to keep in lane, failing to yield right-of-way, driving too fast for conditions or in excess of posted speed limit, failing to obey traffic control devices and laws, and inattention) accounted for about 65% of both car–car and car–truck fatal crashes. This highlights the importance of fundamental, "generic" safe driving practices, including defensive driving, for both commercial and noncommercial drivers.

Regardless of the distribution of critical crash errors between commercial and noncommercial drivers, a principal responsibility of the motor carrier industry is to reduce safety risks traceable to their own drivers. Figure 1 notes two types of commercial driver risk factors: personal situational risk factors and personal constitutional risk factors. Situational factors include driver alertness or fatigue status as influenced by amount of prior sleep, time of day, and hours driving. Non-fatigue-related situational stressors include pressure to deliver on time, economic pressure to drive more miles, and recent events affecting a driver's emotional state (e.g., anger or frustration).

Recent studies (Lancaster and Ward, 2002; Knipling et al., 2004) indicate that commercial driver constitutional factors also significantly affect crash risk. In a review of several instrumented vehicle and driver history studies, Knipling et al. (2004) found that a relatively small percentage of commercial drivers (e.g., 10% to 15%) consistently accounted for a disproportionate percentage of fleet or other aggregate crash risk (e.g., 30% to 50%). Individual constitutional factors potentially predisposing commercial drivers to greater or lesser risk can include demographic, personality, performance, physical or medical, and behavioral history variables.

Not shown in Figure 1 is the occupational and organizational milieu in which commercial drivers operate. Unlike drivers in general, commercial drivers operate within an organizational and operational structure, with important interactions with fleet managers, dispatchers, job demands, their pay system, and customers. Moreover, the commercial motor transport industry operates within a government regulatory and enforcement regime that further characterizes and shapes the total driving system. A full accounting of commercial vehicle and driver safety must embrace all of the factors and influences that affect CMVtransport safety. This circular attempts to explore and encompass this broad domain.

REFERENCES

American Bus Association. http://www.buses.org/safety_data/.

American Trucking Associations. Standard trucking and transportation statistics. Third quarter 2004. www.truckline.com/economics/.

Banks, R. L., and Associates. *Motorcoach Census 2000 Report*. Summer 2000. www.buses.org/press_room/Industry_Facts/. Accessed August 2005.

Blower, D. The Relative Contribution of Truck Drivers and Passenger Vehicle Drivers to Truck/Passenger Vehicle Traffic Crashes. *UMTRI Research Review*, Vol. 30, No. 2, April–June 1999, pp. 1–15.

Blower, D. F., and K. L. Campbell. Methodology of the Large Truck Crash Causation Study. Report No. FMCSA-RI-05-035. Large Truck Crash Causation Study Analysis Series, February 2005.

Carmondy, C. National Transportation Safety Board. April 2002. www.buses.org/safety_data/. Accessed Augus 2005.

Centers for Disease Control. Work-Related Roadway Crashe: Who's at Risk? *Workplace Safety and Health Fact Sheet*. DHHS (NIOSH) Publication No. 2004–137, March 2004.

Council, F. M., D. L. Harkey, A. J. Khattak, and Y. M. Mohamedshah. Examination of Fault, Unsafe Driving Acts, and Total Harm in Car–Truck Collisions. In *Transportation Research Record: Journal of the Transportation Research Board, No. 1830*, Transportation Research Board of the National Academies, Washington, D.C., 2003, pp. 63–71.

Craft, R., and D. Blower. The Large Truck Crash Causation Study. Presented at FMCSA R&T Stakeholder Forum, Arlington, Va., November 2004.

FMCSA. *Driver-Related Factors in Crashes Between Large Trucks and Passenger Vehicles*. Publication No. FHWA-MCRT-99-011, FHWA Office of Motor Carrier and Highway Safety, April 1999b.

FMCSA. Commercial Motor Vehicle Facts. FMCSA, www.fmcsa.dot.gov/factsfigs/cmvfacts. February 2004a.

FMCSA. *Large Truck Crash Facts 2003.* FMCSA-RI-04-033. FMCSA, Washington, D.C., February 2005.

Global Insight, Inc. *The U.S. Truck Driver Shortage: Analysis and Forecasts*. Prepared for the American Trucking Associations, May 2005.

Kostyniuk, L. P., F. M. Streff, and J. Zakrajsek. *Identifying Unsafe Driver Actions that Lead to Fatal Car–Truck Crashes*. AAA Foundation for Traffic Safety, Washington, D.C., April 2002.

Knipling, R. R., L. N. Boyle, J. S. Hickman, J.S. York, C. Daecher, E. C. B. Olsen, and T. D. Prailey. *CTBSSP Synthesis of Safety Practice No. 4: Individual Differences and the "High-Risk" Commercial Driver*. Transportation Research Board of the National Academies, Washington, D.C., 2004.

Lancaster, R., and R. Ward. *The Contribution of Individual Factors to Driving Behaviour: Implications for Managing Work-Related Road Safety.* Health and Safety Executive, Research Report 020, Entec UK Limited, United Kingdom, 2002.

Maccubbin, R. P., B. L. Staples, and M. R. Mercer. *Intelligent Transportation Systems Benefits and Costs: 2003 Update*. FHWA Report No. FHWA-OP-03-075. Mitretek Systems, Inc., May 2003.

TRB. *Conference Proceedings 38: Future Truck and Bus Safety Research Opportunities.* Transportation Research Board of the National Academies, Washington, D.C., 2006.

Treat, J. R., N. S. Tumbas, S. T. McDonald, D. Shinar, R. D. Hume, R. E. Mayer, R. L. Stansifer, and N. J. Catellan. *Tri-Level Study of the Causes of Traffic Accidents: Final Report Volume I: Causal Factor Tabulations and Assessments, Institute for Research in Public Safety.* DOT Publication No. DOT HS-805 085, Indiana University, 1979.

Wang, J. S., R. R. Knipling, and L. J. Blincoe. The Dimensions of Motor Vehicle Crash Risk. *Journal of Transportation and Statistics,* Vol. 2, No. 1, 1999, pp. 19–43.

Zaloshnja, E., and T. Miller. *Revised Costs of Large Truck- and Bus-Involved Crashes*. Final report, FMCSA Contract # DTMC75-01-P-00046, November 2002.

Problem Assessment and Data

DANIEL BLOWER
JOEL L. TICATCH
MICHELE ANN MCMURTRY
KENNETH L. CAMPBELL
RONALD R. KNIPLING
RICHARD J. HANOWSKI
ROBERT A. SCOPATZ
MARGARET SWEENEY

Problem assessment refers to the process by which the traffic safety problems of trucks and buses are discovered and studied. Two approaches to assessing traffic safety problems may be identified: prevalence and risk. Prevalence is simply the frequency with which a traffic safety problem occurs. Crash data files are sufficient by themselves for researchers interested in prevalence. For example, according to the NHTSA's *Traffic Safety Facts, 2002*, 4,542 trucks were involved in a fatal crash in 2002, compared with 27,102 passenger cars. Risk, in contrast, is often expressed as a probability or a rate. Risk might be calculated as the chance of a certain outcome given involvement in a crash or as the number of crashes per some measure of exposure, often miles traveled. Risk as a metric for traffic safety problems can paint a very different picture from prevalence. In 2002, the fatal crash involvement rate for trucks was 2.12 per 100 million VMT, while the rate per 100 million VMT for passenger cars was 1.68.[1]

In this section, the major sources of crash and exposure data that are available to assess truck and bus safety problems are discussed. The primary goal is to provide the reader with a good foundation in the range of data available, an understanding of the strengths and limitations of each, an introduction to some new sources of traffic safety data, and a list of data needs for future research.

CRASH DATA

The principal sources of nationwide commercial vehicle crash data are maintained by NHTSA and FMCSA. NHTSA is the caretaker of two national databases: FARS and the National Automotive Sampling System (NASS)–GES. The third primary national database, the Motor Carrier Management Information System Crash Profile (MCMIS/Crash), is maintained by FMCSA. The Trucks Involved in Fatal Accidents (TIFA) file and Buses Involved in Fatal Accidents (BIFA) file from the University of Michigan Transportation Research Institute (UMTRI) supplement and expand the data available from FARS with a more comprehensive identification and description of trucks and buses in fatal crashes. In addition, in 2001 FMCSA and NHTSA initiated a joint program, LTCCS, to collect detailed and comprehensive data on a sample of 1,000 fatal and serious truck crashes.

Fatality Analysis Reporting System

The FARS database is a census of all U.S. fatal crashes, including commercial truck and bus crashes. Each crash that results in the death of any motorist, other vehicle occupant, or non-motorist within 30 days after occurrence of the incident is entered into FARS. FARS data are collected and coded by specially trained state analysts from police accident reports (PARs) and related documents. Key data elements captured in FARS include date, time, and location of the incident; the numbers of vehicles and people involved; vehicle types and vehicle impact points; drivers' ages and genders; severity of injuries; and description of the first harmful event leading to the incident. Information in the FARS database is not sufficiently detailed to infer crash causality. However, the FARS data, when examined in conjunction with other information, reveal a consistent overrepresentation of large trucks in fatal crashes. FARS became operational in 1975.

The most common truck configurations can be identified in FARS, though the file is less reliable identifying unusual and uncommon configurations, such as triples.[2] No information is available about operator type, though a field for motor carrier number was recently added. This field may potentially be used to add information about the truck operator by matching to an administrative carrier file, such as the MCMIS carrier file. The primary bus types can also be identified in FARS. A "bus use" variable was recently added to capture common uses of buses.[3]

General Estimates System

NASS–GES data are gathered using a national probabilistic sample drawn from police-reported crash rosters. On a weekly basis, a random sample of crashes is selected for capture in the GES database from the crash rosters at more than 400 police jurisdictions across the United States. Whereas the FARS data are limited to fatal incidents, the GES examines both fatal and nonfatal crashes. Large-truck crashes are oversampled in the GES process to ensure that a statistically valid subset of truck incidents is available each year. The data elements captured by the GES process include most of the FARS elements, as well as some additional data items. At the end of each calendar year, after the crash data have been coded, verified, and processed, weighting procedures are applied to the GES database to generate national crash estimates. The outputs include estimates of total large-truck crashes that result in injuries or property damage. The GES data provide estimates only at the national level and cannot be used to infer total numbers of crashes by state; also, like the FARS data, they cannot be used to assess crash causality. The GES data do reveal that large-truck crashes tend to have more severe outcomes than crashes not involving large trucks. The NASS–GES database has been functional since 1988.

Because the GES data are based on a stratified sampling frame, there is a sampling error associated with the weighted estimates from the file. The "GES Technical Notes" appendix of NHTSA's annual *Traffic Safety Facts*[4] provides an equation to calculate standard errors for the estimates. For small sample sizes, these standard errors can be relatively large; this is a problem for small subsets of the file, such as trucks, to say nothing of buses. Estimates of fatal truck involvements from GES are typically 25% to 30% lower than from FARS. The more common truck configurations can be identified in GES, but only "school bus" and "other bus" types are distinguished.[5]

MCMIS Crash File

MCMIS contains information on the safety fitness of commercial motor carriers and shippers of hazardous materials (hazmat) (Figure 1). One system component, the MCMIS/Crash module is intended to be a national census of all crashes involving commercial trucks and buses meeting a relatively low-severity threshold. “Trucks” are defined as vehicles with GVWR in excess of 10,000 lb; “buses” as vehicles designed to transport nine or more passengers. Truck or bus crashes on public roads that result in fatalities, injuries requiring immediate transport from the crash scene, or the towing of one or more vehicles from the crash site are all supposed to be captured in MCMIS. The data elements captured by MCMIS/Crash were defined by the National Governors Association and include identification of the carrier; crash location, date, and time; whether hazmat were involved; total fatalities and injuries; whether a vehicle was towed away; and the sequence of crash events. The crash data are gathered by states, processed using a state-based system called SAFETYNET, and uploaded to MCMIS. Like the FARS and GES information, the MCMIS/Crash data are not sufficiently detailed nor are they intended to assess crash causality. However, in addition to supporting the identification of national trends, the crash data are used in the generation of carrier safety fitness ratings—carriers are rated, in part, according to how their crash experiences compare to other carriers of similar fleet size. The current MCMIS/Crash module has been operational since 1993.

In practice, MCMIS has not yet achieved its intended target as a census of commercial vehicle crashes. State-by-state comparisons of total counts of fatal crashes in FARS and MCMIS reveal substantial offsets between the two systems. Notably, in 2002, MCMIS reported 16% fewer fatal crashes involving large trucks than did FARS.[6] Some of this variance can be explained by differences in definitions of commercial vehicles, etc., used by the two databases.

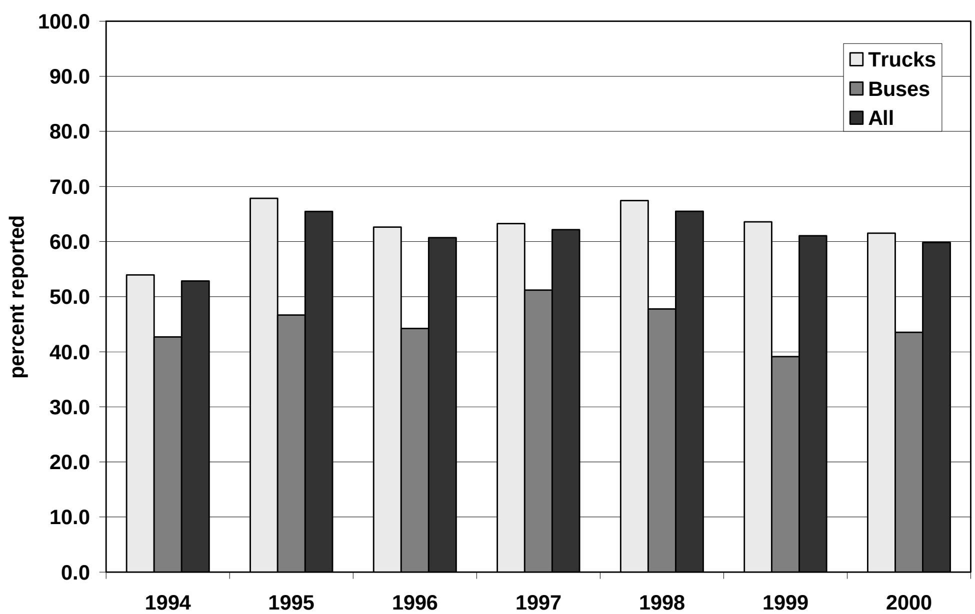

FIGURE 1 Percentage of estimated reportable cases reported to MCMIS/Crash file for trucks, buses, and all (Blower and Matteson, 2003).

However, most of the variance appears to reflect deficiencies in state data-collection and data-sharing procedures. Further, when nonfatal crashes only are considered, the disparity between total crashes reported by GES and MCMIS is even larger.[7] Again, some part of the problem is explained by differences in definitions of "crashes" and "commercial vehicles," but most of the problem almost certainly results from inadequate state data-collection and data-sharing procedures. Prompt reconciliation of the data reported by the different sources is important since it relates to the accurate identification of national crash trends and the safety fitness ratings assigned to individual carriers.

Recent work on MCMIS reporting from Ohio and Missouri shows that there is over-reporting and underreporting to the MCMIS/Crash file. About 20% of the records reported by Ohio do not meet the crash severity threshold. On the other hand, only about 50% of the cases that met the reporting criteria were reported. Reporting rates are substantially lower for buses than for trucks.[8] Findings for Missouri are similar.[9] It is hoped that the findings for these states will be used to incorporate systems that will improve reporting rates.

Trucks Involved in Fatal Accidents and Buses Involved in Fatal Accidents

TIFA and BIFA surveys, conducted by UMTRI, both expand on the FARS database (Figure 2). The TIFA survey has been in operation since 1980; the BIFA survey since 1999. These surveys, which begin with extractions of the fatal truck and bus crashes in the FARS database, involve interviews with the drivers, police officers, emergency personnel, and witnesses involved with specific crashes. Interviewers, reviewing the data for specific crashes, verify the applicability of the crashes and gather detailed information on the physical configuration of the vehicle, the carrier, the driver, and the vehicle trip.

FIGURE 2 Comparison of truck counts in FARS and TIFA data from *Traffic Safety Facts 2002* and TIFA 1980–2000.

TIFA and BIFA provide more accurate and detailed counts of trucks and buses involved in fatal accidents than does the original FARS file because of the detailed follow-up interviews. Typically, the TIFA file counts 5% to 6% more fatal truck involvements annually than the FARS file, with a corresponding difference in the count of fatalities.[10] The BIFA file has a much shorter history, but is expected to show a similar increase in precision and detail. Uncommon yet important truck configurations such as different types of doubles and triples can be identified in the TIFA data. On the other hand, a significant problem with both the TIFA and BIFA data is the time lag before a completed data year is available for analysis.

Large-Truck Crash Causation Study

Beginning in 2001, FMCSA and NHTSA jointly undertook a national, multiyear, large-truck crash causation study to examine the causes and factors contributing to serious large-truck crashes. The LTCCS will determine contributing factors in a sample of crashes involving a truck and either a fatal or serious injury. The goal is to expand understanding of the factors that contribute to truck crashes so that FMCSA and NHTSA can design more effective crash countermeasures. The primary focus of the LTCCS is on crash avoidance research, rather than crashworthiness research.[11] Data collection was to be completed in early 2004, with an analysis file scheduled to be released in the fall of 2004.

The LTCCS uses the existing 24 primary sampling units (PSUs) used in NHTSA's NASS Crashworthiness Data System (CDS). The sample target is 1,000 cases involving a fatality, A, or B injury over the 3 years of data collection. With previous experience from NASS CDS and GES sampling, it was determined that in half of the PSUs, NASS researchers would investigate every qualifying crash, and in the remaining PSUs, every other qualifying crash would be investigated. Data are collected by a two-person team: one full-time NASS researcher and a state truck inspector, certified by Commercial Vehicle Safety Alliance (CVSA) to perform North American Standard Level 1 truck inspections. The NASS researchers arrange with local authorities to be notified as quickly as possible when a qualifying crash occurs. Much of the data collection occur on-scene.

The comprehensiveness and detail collected for the LTCCS is unprecedented—1,000 data elements on 1,000 cases. NASS researchers have 17 data collection forms to complete, although not all are relevant to every crash. Ten forms deal with physical data including general crash information, general vehicle data, occupant assessment, and nonmotorist assessment. The other seven are interview forms, including those for the truck driver, surrogate truck driver (in case truck driver is deceased), other driver, witness, nonmotorist, and motor carrier. The longest form is the 28-page truck driver form covering areas such as crash description, rollover, fire, jackknife, cargo shift, credentials and history, method of payment, physical condition, fatigue issues (sleep history, work schedule, recreational activities), inattention or distraction, perception, decisions, trip, and vehicle.

Truck inspectors complete a form reporting all results from the North American Standard Level 1 truck and truck driver inspections. Vehicle data include 13 critical inspection items such as brakes, exhaust systems, frames, cargo securement, tires, wheels and rims, and fuel systems. Driver data include license, medical card, duty status, and log books. NASS researchers also draft a summary description of the crash based on data collected by the truck inspector and themselves, plus regular PARs and other official documents.

The study design is intended to support relative risk calculations.[12] The data provide extensive information describing the events of the crash, modeled on a system first proposed by Kenneth Perchonok.[13] The goal is to test the association of particular risk factors with specific crash types. With only 1,000 cases, sample sizes may not be large enough to test hypotheses where the effect is expected to be small. Also, since data collection is still under way and the final file has not yet been released, data quality and completeness is currently unknown.

It should be noted that both the study design and data collection have been subject to thorough critiques, including a review committee of TRB, an independent review undertaken by CDC, and background papers by McKnight and Hedlund commissioned by the TRB committee. A full account cannot be attempted here, but the papers cited provide a discussion of the major points at issue.[14]

TRAVEL, CARRIER, DRIVER, AND VEHICLE DATA

An important related issue concerns the availability of accurate and timely data for standardizing and comparing the safety of motor carrier operations. "Exposure" can refer to a range of alternative elements, including VMT, vehicle registrations, and driver licensing. A variety of administrative files exist that collect travel information as well as information on motor carriers, drivers, and vehicle registrations.

Highway Statistics Publication

The primary source for aggregate travel data is the annual *Highway Statistics* publication produced by FHWA.[15] Data are provided to FHWA by the states. This information is supplemented by FHWA analysis and other data from sources such as the Vehicle Inventory and Use Survey (VIUS, formerly the Truck Inventory and Use Survey). The information includes driver licensing, motor vehicle registrations, and highway travel. For example, Table VM-1 provides annual VMT by road type and vehicle type. The truck types are "single unit" (two-axle and six or more tires) and "combination," which includes tractor with semitrailers and the majority of heavy single-unit trucks used regularly with trailers. Road types include three categories of rural roads (Interstate, other arterial roads, and other rural) and two urban categories (urban Interstate and other urban). Combination truck travel was 135 billion vehicle miles in 2001, nearly unchanged from 2000. Table VM-1 also includes motor vehicle registrations and average annual mileage per vehicle. The distribution of travel by vehicle type and road type was provided for each state until 1997. Truck travel by state is no longer provided in *Highway Statistics*. Fatalities and injuries are tabulated by road type and by state, but not by vehicle type. Figure 3 provides an example of the use of FARS data with the VMT estimates from *Highway Statistics* to compare risk in heavy trucks and passenger cars.

Highway Statistics has been published annually since 1945. It provides a relatively consistent source for historical trends in truck travel. The limitation of this publication is that truck travel is not disaggregated beyond two truck types and five road categories. Additional information describing the truck, commodity carried, or carrier was not available from this source. Some of this information is provided by the VIUS, described next.

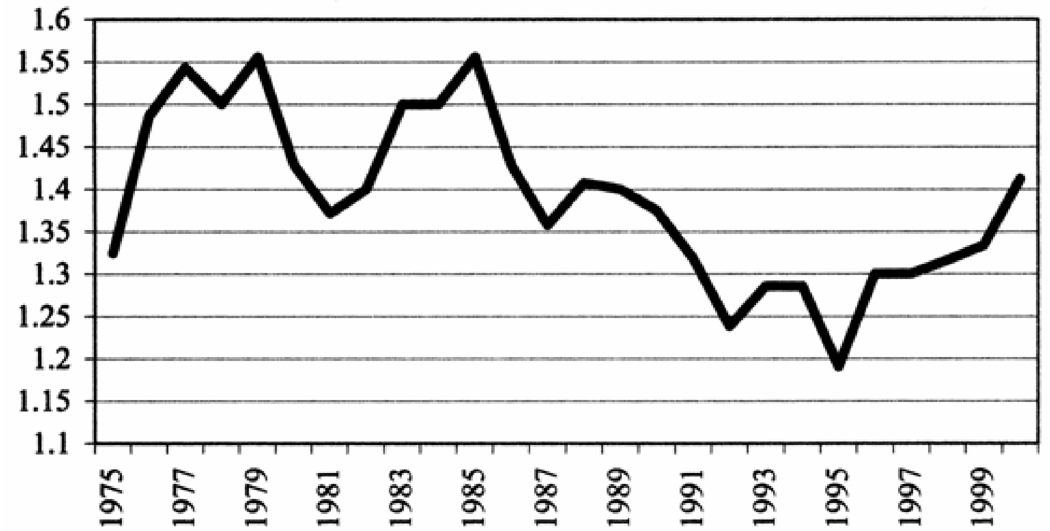

FIGURE 3 Relative risk of large-truck fatal involvement compared with passenger cars per 100 million miles traveled (Moonesighe et al., 2003).

Vehicle Inventory and Use Survey

VIUS is conducted every 5 years by the Bureau of the Census as part of the Census of Transportation. The survey is mailed by R. L. Polk to a probability-based sample of registered truck owners in each state. Although the name has been changed to accommodate an expansion to all registered vehicles, the 2002 sample is limited to trucks as in all past surveys.

VIUS provides the most detailed information on the U.S. truck population. Light-duty and heavy-duty trucks are included. Passenger-carrying vehicles of any kind are not included. Government-owned, military vehicles, ambulances, off-road vehicles, and motor homes are also excluded. Trucks are stratified by body style in each state, and approximately 3,000 trucks are sampled per state. A survey form is mailed to the registered owner of the sampled truck, and the respondent is required by law to complete the form. The resulting response rate is over 80% producing more than 100,000 responses in recent years. The data are all self-reported for the previous year.

In addition to providing the most accurate enumeration of the truck population, information describing the truck and its typical use is also collected. Information on the physical characteristics of sampled vehicles includes fuel type, vehicle type, configuration, weight, overall length, width, and number of axles. Information on vehicle use includes annual mileage, mileage distribution by one-way trip distance, average fuel economy, and commodities carried.

One of the strengths of VIUS is the large sample size. Also, because similar data collection procedures and survey questions have been used over the years, comparisons from year to year are possible. In 1997, a supplemental sample was added for trucks that are registered in one state but the mailing address is in another state. In the past, these trucks were dropped from the sample. Another strength is that R. L. Polk has provided the vehicle identification number (VIN) and the manufacturers' GVWR as contained in the VIN.

A long-standing problem area in this survey has been the area of carrier type. In 1997, for-hire carriers were distinguished from private, but only the for-hire carriers were asked if they operated interstate. For 2002, the question on interstate operating authority was dropped altogether. As a consequence, VIUS cannot estimate the number of trucks subject to FMCSA regulation. Another limitation for safety analysis is that the data represent typical use over the course of a year. Respondents are asked to estimate the average gross combination weight and the distribution of travel by one-way trip distance, but they cannot provide mileage by road type or in rural versus urban areas. The survey would have to focus on a much shorter time period, such as a day or week, to get this level of detail in vehicle use.

Motor Carrier Data

The MCMIS[16] provides a census of interstate carriers, but until recently the information on individual carriers was not updated on a regular basis, and so could be years out of date. In addition, although there is no analogous census of intrastate motor carriers, currently 17 states are voluntarily adding intrastate motor carriers to the MCMIS files.

FMCSA uses the MCMIS census file to track motor carrier safety performance and to assess nationwide motor carrier safety trends. Each census record contains identifying information (such as name and address), business or operation data (operation classification and type of business), cargo classification (type of cargo hauled), hazmat transported, equipment and driver data (such as number of trucks owned, term-leased or trip-leased, and number of drivers), and carrier review data (such as the most recent review date, accident rate, and safety rating).

As of November 2001, the MCMIS census file contained records for about 705,258 active motor carriers and hazmat shippers.[17] According to the definitions of census data elements, carrier operations identifies the carrier as being engaged in interstate, intrastate hazmat, or intrastate nonhazmat transport activities. As of November 2001, the census file contains records for 68,993 intrastate, nonhazmat, nonbus carriers and 532,199 interstate nonhazmat, nonbus carriers.

Currently, states maintain their own records of intrastate motor carriers,[18] but there is no national census information available on intrastate carriers. The FMCSA is implementing a voluntary registration program to include intrastate motor carriers in its census file. At present, 17 states[19] are participating in the voluntary program to issue U.S. DOT numbers, with a state suffix, to intrastate carriers; the number with the state suffix identifies a carrier as an intrastate carrier. Of the 17 states, 13 issue the numbers to both for-hire and private intrastate carriers, whereas four of the 17 states (Georgia, Iowa, Missouri, and Washington) issue U.S. DOT numbers with a state suffix only to for-hire intrastate carriers.

FMCSA issued a final rule on March 1, 2002,[20] requiring interstate motor carriers, beginning April 1, 2002, to update of their information contained in the MCMIS census file every 2 years. The new federal requirement for interstate motor carriers periodically to update their information in the census file does not apply to intrastate carriers.

Vehicle Registration

FHWA produces the *Highway Statistics* report each year, which includes data from the states on vehicle registration.[21] The report indicates that in 2001, 92,045,311 trucks and 749,548 buses were registered in the United States.[22] However, FHWA makes several cautionary statements about these data, primarily the differences between the states in how vehicles are registered and counted. For instance, some states register buses with trucks or automobiles and some states register a tractor–semitrailer as a single unit while others register the tractor and the semitrailer separately.

A second source of vehicle data is from the VIUS conducted every 5 years by the U.S. Census Bureau. VIUS is a probability sample of private and commercial trucks registered in the United States as of July 1 of the data collection year. It excludes vehicles owned by federal, state, and local governments; ambulances; buses; motor homes; farm tractors; unpowered trailer units; and trucks reported to have been sold, junked, or wrecked before July 1 of the data collection year. Data on physical characteristics (e.g., date of purchase, weight, number of axles, overall length, type of engine, and body type) and operational characteristics data (e.g., type of use, lease characteristics, operator classification, base of operation, gas mileage, annual and lifetime miles driven, weeks operated, commodities hauled by type, and hazmat carried) are collected. According to VIUS data for 1997, 72,800,300 private and commercial trucks were registered in the United States.

Driver Data

There is no central database of drivers licensed to drive trucks or buses. Driver information is available primarily as part of state driver license files. These files are maintained separately by each state, and availability of the data for safety analysis varies by state. Typically, state license files include information on the type of vehicle the driver is licensed to driver, traffic violations, and crash involvements. But there is no national file of truck and bus drivers. Accordingly, an estimate of the population of truck and bus drivers varies. FMCSA estimates there are 2.5 to 3.5 million active commercial drivers. The Department of Labor data for 2002 estimates there are 1,520,880 active heavy truck drivers, 197,090 bus (transit or intercity) drivers, and 468,790 school bus drivers.[23] These estimates do not take into account drivers who may use their licenses only occasionally. Moreover, there are many drivers of medium trucks (GVWR 10,001 to 26,000) that are not included in the estimates.

Since 1992, all drivers of commercial motor vehicles with a GVWR or gross combination weight rating over 26,000 lb are required to have a CDL.[24] According to the American Association of Motor Vehicle Administrators, as of June 2001, 10.4 million CDL records were entered in the CDL Information System (CDLIS). CDLIS is primarily a pointer system to records held by the states, rather than a free-standing data system. The CDLIS contains name, date of birth, Social Security number, state driver license number, and “also-known-as” information, along with a pointer to the state(s) that hold the detailed driver history records. Since drivers of medium trucks (10,001 to 26,000 lb GVWR) are not required to possess a CDL, they are not be listed in CDLIS. Moreover, an entry in CDLIS just indicates the possession of a CDL, not that a licensee is employed as a truck driver, much less any detail about a driver’s history.

In addition, because of differences in the information and methods used in collecting information, data collected by the states differ. This makes comparisons between states difficult. Not only are there gaps in existing data, but also no linkage exists currently between the limited data. No way exists to connect individual drivers, vehicles, or carrier information.

INSTRUMENTED-VEHICLE APPROACHES TO CRASH PROBLEM ASSESSMENT

An emerging source of exposure data is the use of data recording equipment on trucks. Global Positioning System (GPS) location devices and a map database in combination with other truck operating information such as speed and loading could provide detailed and accurate exposure data for selected vehicles. Limited applications of such packages have been used in some recent research projects, but not in a large-scale survey. Examples include an evaluation of a rollover stability advisor by UMTRI, a study of fatigue at the Virginia Tech Transportation Institute (discussed below), and a study conducted by Oak Ridge National Laboratories on heavy truck rollover.[25]

Conventional crash problem assessment through retrospective crash investigation has a fundamental shortcoming: it is an after-the-fact reconstruction of the crash. Regardless of the depth of the investigation, it is based entirely on data gathered about the crash after the crash. The effective investigator is one who can sort through the available evidence and determine what happened with some degree of certainty.

Analogous to the sports instant replay, modern recording technology permits direct video and other data recording of driving events. The safety analyst is able to view directly the events in question as they unfolded. This greatly decreases speculation and uncertainty regarding the characteristics and genesis of the event.

Instrumented vehicles may be employed in field operational tests of safety devices or in other experimental studies, but for problem assessment purposes it is most often employed to capture data about drivers' normal driving and safety-significant events occurring during everyday driving. When employed in this manner, the methodology is termed "naturalistic driving."[26]

In the past decade, instrumentation suites for vehicles have advanced significantly in capabilities and reliability.[27] For example, in a study of local and short-haul driver fatigue, Hanowski et al. employed small, in-vehicle video cameras with five camera views, including the forward view, the driver's face, a rearward view, and both the left and right side of the vehicle.[28]

Figure 4 shows a split-screen presentation of the camera views. Other common instrumented-vehicle sensors (or measures available from the vehicle data network) include vehicle speed and acceleration, brake activation, forward and rear radar (to determine range and range rate in relation to other vehicles), and lateral lane position or lane tracking. Data storage may be continuous or triggered by extreme events (e.g., hard braking) or by an "incident button" activated by the driver subject. Measures such as time-to-collision (range–range rate) provide a continuous quantitative measure of instantaneous risk.[29]

When installed in a fleet of vehicles, instrumentation may capture some number of crashes—both police reported and nonpolice reported. However, the methodology is probably most powerful in capturing driver errors and critical incidents rather than crashes. For example, in the local–short-haul study, covering 28,000 vehicle miles of driving, 249 critical incidents were observed and documented. Implicit in the approach is the assumption that such incidents have similar etiologies to crashes, and thus provide data relevant to crashes.

Figure 5 shows Heinrich triangle data for cars and trucks, in which the data distributions are normalized to one injury crash. The fact that injury-to-noninjury ratios are lower for trucks perhaps reflects the greater size of trucks and resulting increased injury potential.[30]

FIGURE 4 Camera views from the local–short-haul study.

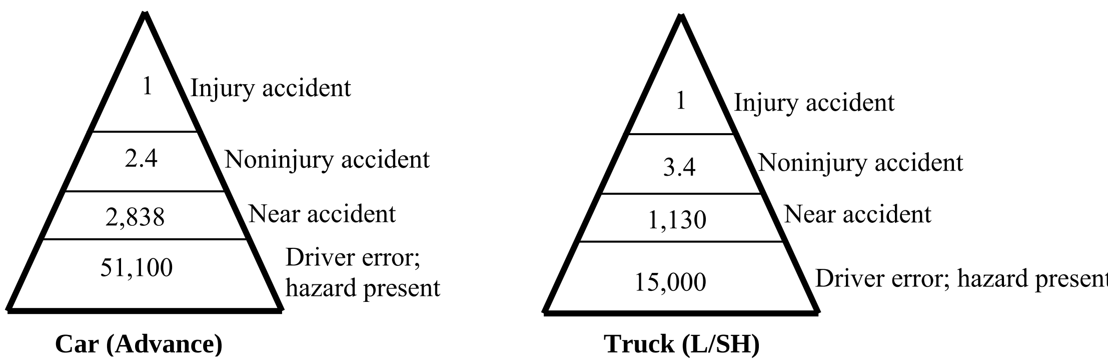

FIGURE 5 Normalized car and truck data using Heinrich's triangle.

In an instrumented-vehicle study of light-vehicle–heavy-vehicle interaction, Hanowski et al. captured and reviewed 210 safety incidents, and observed that 164 (78%) were initiated by the actions of surrounding light vehicles, while 46 (22%) were initiated by the heavy-vehicle subjects in the study. The most common general error by light-vehicle drivers was not allowing sufficient gaps or clearance while making a lane change. There were no recorded light-vehicle–heavy-vehicle crashes in the study.[31]

As noted earlier in this chapter, the lack of detailed exposure or control data limits valid inference from conventional crash databases. In instrumented-vehicle studies, random time epochs can be observed and classified according to environmental, roadway, vehicle, and driver variables. Control or baseline frequencies or levels of conditions or behaviors, compared with values seen in critical incidents, can indicate whether the condition or factor is associated with increased risk. For example, in a recently completed naturalistic driving study encompassing 95 long-haul drivers and about 48,000 h of recorded driving, the conditions of occurrence of 915 safety-critical events were compared with those of 1,072 randomly selected driving epochs.[32] Driving on undivided highways, in construction zones, in dense traffic, and during evening rush hours was associated with greatly increased risk of incident involvement. Weather had little overall association with incident involvement, and incidents were actually less likely during darkness than daylight, perhaps because of the general covariation of darkness with low traffic density.

In addition to quantifying risks associated with driving situations and behaviors, the larger number of incidents observed in naturalistic driving studies supports more powerful statistical studies of driver individual differences and personal risk factors. In the local–short-haul study, 5% of the drivers were found to account for 26% of 77 observed commercial driver critical incidents (unsafe driver actions or near crashes), and 19% of the drivers accounted for 60% of incidents. In contrast, the best one-third of the drivers were involved in no incidents. The number of total incidents was sufficiently high to preclude these findings being reflective of mere random occurrence.

A new and more extensive heavy-truck naturalistic driving study could be imagined in which a wide array of driver and situational safety factors might be studied to determine the frequency of these factors and the increased or decreased crash–incident risk associated with them. Comparisons could permit the derivation of odds–ratios and other statistics quantifying the risk associated with various factors.[33] Not only could the risk associated with individual factors be determined; one could combine assessments of individual risk factors into a multiple-factor “best prediction” of increased risk. Categories of risk factors might include driver demographics, behavioral history, physical or medical characteristics, driver performance capabilities, personality, off-duty behaviors (both general and immediately preceding driving samples), carrier and operation type, and precrash driving actions and behaviors. One of the key objectives of planned Future Strategic Highway Research Program (F-SHRP) research is to use naturalistic driving methods to determine the association of such factors to driver crash and incident risk. The F-SHRP program will primarily study noncommercial drivers but will, it is hoped, include truck data collection as well.

RESEARCH NEEDS

- Detailed exposure data for both trucks and buses. This might include VMT by time of day, motor carrier type (private or for-hire, interstate or intrastate), bus type, truck configuration, cargo loading, road type, light condition, weather, driver age, and driver experience.
- More detailed crash data on nonfatal crashes for trucks and buses, such as better truck configuration and bus type identification and larger sample sizes for improved accuracy.
- Intrastate carrier information similar to that available on interstate carriers in the MCMIS Carrier file.
- Comprehensive information on commercial vehicle drivers, including both CDL holders and drivers of medium trucks and small buses.

DATA SOURCES

File	Source
FARS and GES	The files may be downloaded from ftp://ftp.nhtsa.dot.gov/ or http://www.transtats.bts.gov/.
TIFA and BIFA	UMTRI, Center for National Truck and Bus Statistics.
MCMIS/Crash files	The files may be downloaded from the FMCSA area at www.transtats.bts.gov/.
VIUS	See www.census.gov/econ/www/viusmain.html.
FHWA's *Highway Statistics*	See annual publication. FHWA website at www.fhwa.dot.gov/policy/ohpi/hss/index.htm provides some of the tables.
FMCSA LTCCS	To be released in 2005.

NOTES

1. *Traffic Safety Facts, 2002*. DOT HS 809 620. NHTSA, U.S. Department of Transportation, January 2004, p. 17.
2. Blower, D., and A. Matteson. Large Trucks in FARS and TIFA, 1999. UMTRI 2002-17. University of Michigan Transportation Research Institute, Ann Arbor, July 2002.
3. FARS Coding and Validation Manual, 2002. NHTSA, U.S. Department of Transportation.
4. *Traffic Safety Facts 2002*. NHTSA, U.S. Department of Transportation, January 2004.
5. General Estimates System Coding and Editing Manual, 2001. NHTSA, U.S. Department of Transportation.
6. *Comparison of FARS and MCMIS: Large Trucks Involved in Fatal Crashes by State*, August 2003 Snapshot, FMCSA, 2003.
7. Blower, D., and A. Matteson. *Evaluation of the Motor Carrier Management Information System Crash File, Phase One*. University of Michigan Transportation Research Institute, Ann Arbor, March 2003.
8. Blower, D., and A. Matteson. *Patterns of MCMIS Crash File Underreporting in Ohio*. University of Michigan Transportation Research Institute, Ann Arbor, August 2003.
9. Blower, D., and A. Matteson. *Evaluation of Missouri Crash Data Reported to MCMIS Crash File*. University of Michigan Transportation Research Institute, Ann Arbor, forthcoming.
10. Compare Tables 3 and 11 from *Traffic Safety Facts, 2001* with Tables 1-1 and 1-7, respectively, in Blower, D., and A. Matteson. *Trucks Involved in Fatal Accidents Factbook 2000*. Center for National Truck Statistics, University of Michigan Transportation Research Institute, July 2003.
11. Craft, R., and D. Blower. Federal Crash Databases: Shifting the Paradigm: The Large Truck Crash Causation Study. Compendium of Technical Papers. 73rd ITE Annual Meeting, Seattle, Wash., 2003.
12. Blower, D., and K. L. Campbell. *The Large Truck Crash Causation Study*. UMTRI Report No. 2002-31. University of Michigan Transportation Research Institute, Ann Arbor.
13. Perchonok, K. Accident Cause Analysis. DOT-HS-053-1-109. Cornell Aeronautical Laboratory, Inc., July 1972.
14. Committee for Review of the Federal Motor Carrier Safety Administration's Large Truck Crash Causation Study. Final Letter Report on Truck Crash Causation Study. Available at trb.org/publications/reports/tccs_sept_2003.pdf; accessed August 31, 2005. Centers for Disease Control and Prevention, *Evaluation of the Large Truck Crash Causation Study Design*, Atlanta, Ga., March 2003. J. A. McKnight, *Investigative Analysis of Large Truck Accident Causation*, Transportation Research Board of the National Academies, Washington, D.C., 2003. J. Hedlund, *Statistical Analyses of Large Truck Crash Causation Study Data: A Report to the Committee for*

Review of the Federal Motor Carrier Safety Administration's Truck Crash Causation Study, Highway Safety North, 2003.
15. *Highway Statistics 2002*. FHWA-PL-03-010. FHWA, U.S. Department of Transportation, 2003.
16. The MCMIS is a computerized system whereby the FMCSA maintains a comprehensive record of the safety performance of the motor carriers (truck and bus) and hazmat shippers that are subject to the federal motor carrier safety regulations (FMCSRs) or to the hazardous materials regulations (HMRs). The MCMIS contains census, crash, inspection, enforcement, and compliance review information.
17. A record is considered inactive if the entity is no longer in business or is no longer subject to the FMCSRs or the HMRs. MCMIS Census File Documentation, Office of Motor Carriers, FHWA, U.S. Department of Transportation, July 1998.
18. Some states maintain information on for-hire and private carriers, and some maintain information only on for-hire carriers.
19. Colorado, Connecticut, Florida, Georgia, Idaho, Indiana, Iowa, Kansas, Kentucky, Maine, Missouri, Nebraska, Oklahoma, Oregon, Utah, Washington, and Wyoming. Of the 68,993 carriers in the MCMIS census file, 61,844 (90%) are from these 17 states.
20. *Federal Register*, Vol. 67, No. 41, Friday, March 1, 2002, pp. 9410–9416. The actual regulation is 49 CFR 390 [amended], section 390.19.
21. The *Highway Statistics* report contains data on motor fuel, motor vehicles, driver licensing, highway–user taxation, state and local government highway finance, highway mileage, and federal aid for highways.
22. www.fhwa.dot.gov/ohim/hs01/mv.htm; accessed on January 7, 2004.
23. www.bls.gov/oes/2002/oes533032.htm; accessed on January 2, 2004.
24. The CDL program and CDLIS were created by the Commercial Motor Vehicle Safety Act of 1986 (CMVSA). Under federal standards (CFR 49 Parts 383, 384 and 391) a driver must have a CDL to operate a commercial motor vehicle with a GVWR of 26,001 lb or more, hauling placarded amounts of hazmat, or transporting at least 16 passengers, including the driver.
25. Winkler, C., et al. *Field Operational Test of the Freightliner/Meritor WABCO Roll Stability Advisor & Control at Praxair;* UMTRI 2002-24; University of Michigan Transportation Research Institute. Stevens, S., et al.; *Truck Roll Stability Data Collection and Analysis;* ORNL/TM-2001/116; Center for Transportation Analysis, Oak Ridge Natonial Laboratory. Oak Ridge, Tenn., July 2001.
26. Neale, V. L., S. G. Klauer, R. R. Knipling, T. A. Dingus, G. T. Holbrook, and A. D. Peterson; *100 Cars Naturalistic Driving Safety Study: Phase I Report*; Contract DTNH22-00-C-07007; NHTSA November 2002.
27. Hanowski, R. J., A. S. Keisler, and W. W. Wierwille. *Study of Light Vehicle–Heavy Vehicle Interaction, Phase A: Study of Light Vehicle–Local–Short Haul Vehicle Interaction*. Contract DTFH61-96-C-00105, FMCSA Final Report, 2001. See also Neale, op. cit.
28. Hanowski, R. J., W. W. Wierwille, S. A. Garness, and T. A. Dingus. *Impact of Local–Short Haul Operations on Driver Fatigue*. Final Report No. DOT-MC-00-203. FMCSA, U.S. Department of Transportation, September 2000.
29. Campbell, K. L., M. Lepofsky, and A. Bittner. *Detailed Planning for Research on Making a Significant Improvement in Highway Safety: Study 2—Safety*. Prepared for the Future Strategic Highway Research Program, Transportation Research Board of the National Academies, Washington, D.C., September 2003.
30. Op. cit., Hanowski et al., 2000.
31. Op. cit., Hanowski et al., 2001.
32. Knipling, R. R., R. J. Hanowski, J. S. Hickman, R. L. Olson, T. A. Dingus, and R. J. Carroll. Exposure-Risk Analysis of Large Truck Naturalistic Driving Data. *Proceedings of the 2005 Truck and Bus Safety and Security Symposium*, Alexandria, Va., November 14–16, 2005.
33. Op. cit., Campbell, 2003.

RESOURCES

Blower, D., and K. L. Campbell. *The Large Truck Crash Causation Study*. UMTRI Report No. 2002-31. Center for National Truck Statistics, University of Michigan Transportation Research Institute.

Blower, D., and A. Matteson. *Evaluation of Missouri Crash Data Reported to MCMIS Crash File*. University of Michigan Transportation Research Institute, Ann Arbor, forthcoming.

Blower, D., and A. Matteson. *Evaluation of the Motor Carrier Management Information System Crash File, Phase One*. University of Michigan Transportation Research Institute, Ann Arbor, March 2003.

Blower, D., and A. Matteson. *Large Trucks in FARS and TIFA, 1999*. UMTRI 2002-17. University of Michigan Transportation Research Institute, Ann Arbor, July 2002.

Blower, D., and A. Matteson. *Patterns of MCMIS Crash File Underreporting in Ohio*. University of Michigan Transportation Research Institute, Ann Arbor, August 2003.

Blower, D., and A. Matteson. *Trucks Involved in Fatal Accidents Factbook 2000*. Center for National Truck Statistics, University of Michigan Transportation Research Institute, July 2003.

Campbell, K. L., M. Lepofsky, and A. Bittner. *Detailed Planning for Research on Making a Significant Improvement in Highway Safety: Study 2—Safety*. Prepared for the Future Strategic Highway Research Program, Transportation Research Board of the National Academies, Washington, D.C., 2003.

Centers for Disease Control and Prevention. *Evaluation of the Large Truck Crash Causation Study Design.* Atlanta, Ga., March 2003.

Committee for Review of the Federal Motor Carrier Safety Administration's Large Truck Crash Causation Study. Final Letter Report on Truck Crash Causation Study. Available at trb.org/publications/reports/tccs_sept_2003.pdf. Accessed August 21, 2005.

Craft, R., and D. Blower. Federal Crash Databases: Shifting the Paradigm: The Large Truck Crash Causation Study. Institute of Transportation Engineers International, Compendium of Technical Papers: 73rd ITE Annual Meeting, Seattle, Wash., 2003.

FHWA. *Highway Statistics 2002.* FHWA-PL-03-010. FHWA, U.S. Department of Transportation.

FHWA. *Motor Carrier Management Information System Census File Documentatio*n. Office of Motor Carriers, FHWA, U.S. Department of Transportation, July 1998.

Hanowski, R. J., A. S. Keisler, and W. W. Wierwille. *Study of Light Vehicle–Heavy Vehicle Interaction, Phase A: Study of Light Vehicle–Local–Short Haul Vehicle Interaction*. FMCSA final report, Contract DTFH61-96-C-00105, 2001.

Hanowski, R. J., W. W. Wierwille, S. A. Garness, and T. A. Dingus. *Impact of Local/Short Haul Operations on Driver Fatigue.* Final Report No. DOT-MC-00-203. FMCSA, U.S. Department of Transportation, September 2000.

Hedlund, J. *Statistical Analyses of Large Truck Crash Causation Study Data: A Report to the Committee for Review of the Federal Motor Carrier Safety Administration's Truck Crash Causation Study*. Highway Safety North, 2003.

McKnight, A. J. *Investigative Analysis of Large Truck Accident Causation.* Transportation Research Board of the National Academies, Washington, D.C., 2003.

Moonesighe, R., A. Langthorne, U. Shankar, S. Singh, R. Subramanian, and J. Tessmer. *An Analysis of Fatal Large Truck Crashes.* DOT HS 809 569. NHTSA, U.S. Department of Transportation, March 2003.

NHTSA. *Comparison of FARS and MCMIS: Large Trucks Involved in Fatal Crashes by State*, FMCSA, 2003.

NHTSA. *FARS Coding and Validation Manual, 2002.* NHTSA, U.S. Department of Transportation.

General Estimates System Coding and Editing Manual, 2001. NHTSA, U.S. Department of Transportation.

NHTSA. *Traffic Safety Facts 2002.* NHTSA, U.S. Department of Transportation, January 2004.

Neale, V. L., S. G. Klauer, R. R. Knipling, T. A. Dingus, G. T. Holbrook, and A. D. Peterson. *100 Cars*. Naturalistic Driving Safety Study: Phase I Report. Contract DTNH22-00-C-07007. NHTSA, U.S. Department of Transportation, November 2002.

Perchonok, K. Accident Cause Analysis. DOT-HS-053-1-109. Cornell Aeronautical Laboratory, Inc., July 1972.

Stevens, S. S., S. M. Chin, K. A. Hake, H. L. Hwang, J. P. Rollow, and L. F. Truett. *Truck Roll Stability Data Collection and Analysis*. ORNL/TM-2001/116. Center for Transportation Analysis, Oak Ridge Natonal Laboratory. Oak Ridge, Tenn., July 2001.

Winkler, C., et al. *Field Operational Test of the Freightliner/Meritor WABCO Roll Stability Advisor and Control at Praxair.* UMTRI 2002-24. University of Michigan Transportation Research Institute, Ann Arbor, September 2002.

Motor Carrier Safety Laws and Regulations

DEBORAH M. FREUND

Laws and regulations governing motor carrier transportation have historically been concentrated in three main areas: regulation of the business of highway transportation for hire, regulation to protect the highway infrastructure, and regulation of safety (*1*). Although this chapter will focus on safety, the other two areas have been important and significant influences.

This chapter begins with a discussion of the development of laws influencing motor carrier, vehicle, and driver safety, starting with the discussions that led to the development of the Motor Carrier Act (MCA) of 1935, and ending with the Motor Carrier Safety Improvement Act (MCSIA) of 1999. It next reviews the responsibilities of the various U.S. government agencies that have regulatory and safety oversight responsibility over various aspects of motor carrier safety. Next, it briefly discusses the process of regulatory development. Finally, it looks briefly into the future to suggest potential opportunities for research.

THE EARLY YEARS: 1930s–1950s

The development of the motor carrier industry began shortly after World War I. The motor carrier industry was initially regulated by many of the states, but these regulations were not uniform and universal in their application. The U.S. Congress had discussed the issues related to the infant motor carrier industry from 1909 through 1932 (*2*, *3*).

The Interstate Commerce Commission (ICC), which had been in existence since 1887, recommended federal regulation of motor carriers as early as 1928. ICC's interest in safe transportation of hazmat by highway grew from the agency's original focus on hazmat transportation by rail, with regulations being promulgated in 1930 and revised in 1936 (*4*). The lack of uniform regulations, or none at all in some states, provoked allegations of disturbing abuses and caused concerns in both the economic and safety arenas. The Federal Coordinator of Transportation, a post created in 1933 by the Emergency Railroad Transportation Act of 1933 to promote transportation development for the nation, studied the highway transportation situation. In 1934, the Federal Coordinator recommended regulation of motor carrier activities by the federal government. The report concluded that motor carriers should be regulated in a way similar to the railroad industry, which had been regulated by ICC for the previous 50 years. The report recommended regulating the economic, as well as the safety, aspects of the motor carrier industry (*3*).

Following this report, Congress again discussed the regulation of motor carriers and passed the MCA of 1935 (49 Stat. 546, ch. 498). The MCA was enacted as Part II of the Interstate Commerce Act. It placed responsibility on ICC to regulate for-hire motor carriers of passengers and of freight in the areas of economic health and safety of operations. This law established economic and safety regulations on a national basis (*5*).

ICC promulgated its commercial regulations though formal (hearings) rule making and its safety regulations through informal (notice and comment) rule making. The body of safety regulations grew rapidly. Most of the early regulations addressed qualifications and safety of drivers. These were followed by an extensive body of regulations on vehicle safety.

THE TRANSITIONAL YEARS: 1960s–1990

The early years of this period saw several momentous changes in the legislative view and regulatory oversight of highway and motor carrier safety[1] with the establishment of the U.S. DOT as a cabinet-level agency to bring together a broad range of transportation safety responsibilities, and the independent National Transportation Safety Board (NTSB). Additional legislation led to organizational changes in the DOT and to the establishment of different agencies with complementary responsibilities for highway, vehicle, and driver safety.

The year 1966 was a watershed year for highway safety. It saw the passage of the Highway Safety Act and the National Traffic and Motor Vehicle Safety Act. Also that year, the Department of Transportation Act of 1966 provided for the creation of a cabinet-level department (80 Stat. 931). The act transferred to the new department many transportation activities conducted by other agencies, including the Department of Commerce's Bureau of Public Roads, which became FHWA.

The 1966 act also created NTSB. NTSB is an independent agency charged by Congress with investigating every civil aviation accident in the United States and significant accidents in the other modes of transportation—railroad, highway, marine, and pipeline—and issuing safety recommendations aimed at preventing future accidents. NTSB commenced operations on April 1, 1967. NTSB relied on the U.S. DOT for funding and administrative support until 1975. The Independent Safety Board Act severed all organizational ties to U.S. DOT (*6*).

In December 1967, the regulatory responsibility for CMV safety was delegated to the Bureau of Motor Carrier Safety (later Office of Motor Carrier Safety) within FHWA.

NHTSA, an operating administration of the U.S. DOT, was established by the Highway Safety Act of 1970 (84 Stat. 1739). It succeeded the National Highway Safety Bureau, at that time part of the FHWA. Its safety programs have their genesis in the authority granted by the National Traffic and Motor Vehicle Safety Act of 1966 (80 Stat. 718) and the Highway Safety Act of 1966 (80 Stat. 731) (*7*).

The Hazardous Materials Transportation Act of 1974 (HMTA) (88 Stat. 2156) granted the Secretary of Transportation regulatory and enforcement authority to provide adequate protection against the risks to life and property inherent in the transportation of hazmat in commerce. The HMTA was designed to replace a patchwork of state and federal laws and regulations concerning hazmat transportation with a framework of uniform, national regulations. The Hazardous Materials Transportation Uniform Safety Act of 1990 (104 Stat. 3244) amended the HMTA.

The MCA of 1980 (94 Stat. 793)established minimum levels of financial responsibility for motor carriers of property, and the Bus Regulatory Reform Act of 1982 (96 Stat. 1102) established minimum levels of financial responsibility of motor carriers of passengers. The Surface Transportation Assistance Act (STAA) of 1982 (96 Stat. 2097), among its other provisions, authorized the Secretary of Transportation "to make grants to states for the development or implementation of programs for the enforcement of federal rules, regulations, standards, and orders applicable to CMVsafety and compatible state rules, regulations, standards, and orders." This was the foundation for the Motor Carrier Safety Assistance Program (MCSAP).

The MCA of 1984, the first fundamental revision of the motor carrier safety statutes since 1935, directed the U.S. DOT to establish minimum vehicle and operational standards and to increase fines and strengthen administrative enforcement mechanisms and required states to conduct vehicle inspections at least annually (98 Stat. 2834) (*5*).

The CMVSA of 1986 (100 Stat. 3207-170) established the CDL Program and the CDLIS to serve as a clearinghouse and repository of commercial driver licensing and conviction data. The goal of the CMVSA was to improve highway safety by ensuring that each driver of large trucks and buses had only one license and that drivers passed knowledge and skills tests in order to obtain that license. The CMVSA also requires states to ensure that drivers convicted of certain serious traffic violations are prohibited from operating CMVs. The Secretary of Transportation was directed to monitor the states' compliance with the standards established under the CMVSA.

Section 15 of the Sanitary Food Transportation Act of 1990 (P.L. 101-500, 104 Stat. 1213, 1218) among other things, prohibited motor carriers of passengers and hazmat from operating if they received unsatisfactory safety ratings from the FHWA–OMC.

ACCELERATING CHANGE: THE 1990s AND BEYOND

The 1990s saw greatly increased legislative activity notable for its scope and specificity. Among other things, this decade brought the sunset of ICC and the elevation of motor carrier safety to the status of an operating administration of U.S. DOT.

The Omnibus Transportation Employee Testing Act of 1991 (105 Stat. 952) requires all motor carriers to perform preemployment, reasonable cause, random, periodic, and post-accident drug testing of all employees in safety-sensitive positions. It also expands upon the prohibition of alcohol abuse by adding requirements for random, reasonable cause, and post-accident testing. It should be noted that prohibitions against alcohol and drug use by CMV drivers have been a part of the safety regulations since 1937 (*8*).

Section 345 of the National Highway System Designation Act of 1995 (109 Stat. 568, at 613) created a statutory exemption from all of the hours-of-service (HOS) provisions for individuals transporting crops and farm supplies within a 100-air-mile radius during planting and harvesting seasons, and a more limited exemption (allowing a more rapid 24-h restart of the 60- or 70-h HOS calculation) for drivers of utility service vehicles, CMVs transporting groundwater well drilling rigs, and construction materials and equipment. FHWA, however, was authorized to conduct rule making on the advisability of each of these exemptions (except that concerning water well drilling rigs) and to monitor the effects of the exemptions, reporting any adverse safety impacts to Congress. FHWA adopted all of the required exemptions in April 1996 [49 CFR 395.1(k), (l), (m), and (n)].

The ICC Termination Act of 1995 (109 Stat. 803) abolished ICC and transferred certain ICC functions and proceedings either to the Surface Transportation Board or the Secretary of Transportation. Responsibility for the collection and dissemination of motor carrier financial information was transferred to the Secretary of Transportation, who delegated that responsibility to the Bureau of Transportation Statistics.

The Transportation Equity Act for the 21st Century (TEA-21), enacted in 1998 (112 Stat. 107), provided the authority to strengthen motor carrier safety enforcement, and to develop new approaches to improving motor carrier safety compliance assurance. It augmented the basic motor carrier grant program by expanding the toolbox of enforcement techniques, closing loopholes that permit unsafe practices, and allowing development of innovative approaches to regulations. Under the provisions of TEA-21, the National Motor Carrier Safety Program was restructured to promote performance-based activities and flexibility for state grantees by allowing them to invest in areas providing the greatest potential for crash reduction based on their own circumstances. The act was also intended to strengthen federal and state enforcement tools, and provide innovative approaches to improving motor carrier compliance. Finally, the act enhances the information systems that support all national motor carrier safety activities and provide the analytical foundation for future safety improvements (*9*).

Among its other provisions, TEA-21 provided new legislative authority for motor carrier safety regulations in several key matters:

1. Imposed mandatory shutdown on all unfit carriers, strengthening the authority of the secretary to order unsafe motor carriers to cease operations.
2. Required the secretary to develop an implementation plan to identify the procedures that would be followed, if Congress subsequently provided authority, to enforce safety regulations when violated by shippers and others.
3. Removed barriers to effective application of penalties and established a $10,000 maximum penalty for all nonrecordkeeping violations of the safety regulations.
4. Amended the definition of CMVto reflect the actual gross vehicle weight rather than just the GVWR. It also amended the definition of CMV in 49 U.S.C. 31132(1) to cover vehicles "designed or used to transport more than 8 passengers (including the driver) for compensation." On August 12, 2003, FMCSA issued a final rule amending the FMCSRs to require that motor carriers operating CMVs, designed or used to transport between nine and 15 passengers (including the driver) in interstate commerce, must comply with the applicable safety regulations when they are directly compensated for such services and when the vehicle is operated beyond a 75-air-mile radius (86.3 statute-miles or 138.9 km) from the driver's normal work-reporting location. [The 75-air-mile radius has since been overruled by Section 4136 of the Safe, Accountable, Flexible, Efficient Transportation Equity Act: A Legacy for Users (SAFETEA-LU.)]
5. Revised the authority of the secretary to issue waivers and exemptions from safety regulations and CDL requirements and establishes procedures for exemption pilot programs. Safety prerequisites for exemptions and pilot programs were established.

Establishment of Federal Motor Carrier Safety Administration

On October 9, 1999, in response to congressional appropriations action, the Secretary of Transportation rescinded the authority previously delegated to the FHWA to perform motor carrier functions and operations, and to carry out the duties and powers related to motor carrier safety vested in the secretary by chapters 5 and 315 of Title 49, United States Code. In order to ensure the continuation of motor carrier safety oversight functions, this authority was redelegated to the director, Office of Motor Carrier Safety, a new position created within the Office of the Secretary.

On December 9, 1999, the MCSIA of 1999 (113 Stat. 1748) established a new operating administration, FMCSA, to improve the motor carrier safety program. FMCSA's first official day of operations was January 1, 2000.

The MCSIA required the new agency to address numerous items through rule making. In order to provide proper safety oversight of the regulated motor carrier community, the agency must know the characteristics of individual motor carriers. Section 217 of MCSIA directed U.S.

DOT to require periodic updating (once every 2 years) of the motor carrier identification report (Form MCS-150) filed by each motor carrier conducting operations in interstate or foreign commerce (*14*).

Section 208 of MCSIA revised the definition of an imminent hazard to cover "any condition of vehicle, employee, or CMV operations which substantially increases the likelihood of serious injury or death if not discontinued immediately." The previous definition was "any condition of vehicle, employee, or CMV operations which is likely to result in serious injury or death if not discontinued immediately." Because this test was virtually impossible to meet, Congress amended the standard to make it more usable (*11*).

Enactment of SAFETEA-LU

Authorization

SAFETEA-LU (119 Stat. 1144) was enacted on August 10, 2005. FMCSA's administrative expenses and grant programs [MCSAP, Border Enforcement, CDL, Performance and Registration Information Systems Management (PRISM), Commerical Vehicle Information Systems and Networks (CVISN), etc.] were reauthorized, and the agency was authorized to make grants to states for improvements in the collection and handling of safety data.

Medical Provisions

FMCSA was authorized to establish a National Registry of Medical Examiners. The agency will eventually reject driver physicals performed by examiners not listed on the registry and will review some of the physicals of listed examiners to ensure that standards are maintained. Drivers with insulin-controlled diabetes must be allowed to operate CMVs in interstate commerce and may not be held to a higher standard than other drivers.

New Programs

Companies providing preemployment screening services to the motor carrier industry must be given electronic access (with certain safeguards) to the MCMIS to check on accidents, inspection reports and serious driver-related safety violations. FMCSA must undertake rule making to insure that intermodal equipment is safe and systematically maintained. The regulations apply to railroads, steamship lines and others that tender intermodal chassis or trailers to motor carriers. The agency was authorized to require private motor carriers, like for-hire carriers, to file proof of financial responsibility.

Enforcement

If FMCSA finds that an officer of a for-hire motor carrier has engaged in a pattern of non-compliance with the safety regulations, the agency can suspend or revoke any part of the carrier's registration. Civil penalties for out-of-service violations and false records were at least doubled and new penalties for denial of access to records were created. FMCSA employees were authorized to order CMV drivers to stop and submit to inspection of the vehicle, driver, cargo and records. When FMCSA orders an interstate motor carrier out of service, the carrier's intrastate operations must also cease.

Commercial Driver's License

U.S. DOT was required to develop and publish a comprehensive national plan to modernize the CDLIS and then to implement the plan. Substantial grant funds were authorized to enable states to comply with the plan. A parallel grant program to improve state CDL operations was also authorized. Finally, DOT must convene a task force to study current impediments and foreseeable challenges to the effectiveness of the CDL program.

Hours of Service Exemptions

Drivers of trucks operated by utilities were completely exempted from the federal HOS regulations, and states were preempted from adopting similar regulations. Operators of trucks used in movie or television production were allowed to comply with the pre-2003 HOS regulations, which enabled them to extend their working day by the amount of off-duty time they take during the day. The previous HOS exemption for drivers of vehicles transporting "agricultural commodities or farm supplies" was expanded by defining those terms to include livestock, animal feed, and nonprocessed food. A new HOS exemption covered drivers west of Interstate 81 in New York transporting grapes during the harvest season, as defined by the state, within a 150-mi radius of the point where they are picked; the exemption expires with SAFETEA-LU. Another new exemption applied to drivers of CMVs who transport propane winter heating oil or respond to pipeline emergencies; both categories of driver are exempt from many federal regulations if compliance would prevent them from responding to an "emergency condition requiring immediate response."

FMCSA Regulatory and Program Responsibilities

This section briefly describes the FMCSA's major regulatory and program responsibilities. They are discussed in more detail in the section on enforcement and compliance.

Federal Motor Carrier Safety Regulations and Hazardous Materials Regulations

FMCSA develops, maintains, and enforces federal regulations that promote carrier safety. The FMCSRs establish safe operating requirements for commercial vehicle drivers, carriers, vehicles, and vehicle equipment. FMCSA also enforces for highway transportation the HMRs issued by the Pipeline and Hazardous Materials Safety Administration (PHMSA), which are designed to ensure the safe and secure transportation of hazmat. These rules address the classification of hazmat, proper packaging, employee training, hazard communication, and operational requirements. FMCSA's border and international safety activity supports the development of compatible motor carrier safety requirements and procedures throughout North America. FMCSA works closely with the governments of Canada and Mexico to ensure that these countries' motor carriers, drivers, and vehicles operating in the United States meet the same safety standards as U.S. carriers.

Motor Carrier Safety Assistance Program

This is a federal grant program that was developed in response to congressional direction in the 1982 Surface Transportation Assistance Act. It provides states with financial assistance to hire staff and implement strategies to enforce state laws and regulations compatible with the FMCSRs and HMRs. MCSAP funds are used to conduct roadside inspections and review motor carriers' compliance with the state versions of the FMCSRs and HMRs. MCSAP funds promote detection and correction of CMV safety defects, commercial vehicle driver deficiencies, and unsafe motor carrier practices before they become contributing factors to crashes and hazmat incidents.

Commercial Driver's License Program

FMCSA develops, monitors, and ensures compliance with the CDL standards for drivers, motor carriers, and states.

Motor Carrier Safety Identification and Information Systems

FMCSA provides safety data, including state and national crash statistics, current analysis results, and detailed motor carrier safety performance data to industry and the public. The data allow federal and state enforcement officials to target inspections and investigations on higher risk carriers, vehicles, and drivers.

New Entrant Safety Assurance Process

Between 40,000 and 50,000 new entrant motor carriers begin operating CMVs each year. FMCSA ensures that these motor carriers are knowledgeable about applicable FMCSRs and HMRs. There is an 18-month monitoring period for new applicants, which requires the carrier to pass a safety audit and maintain safe operations to receive permanent U.S. DOT registration. New entrant motor carriers that fail to maintain adequate basic safety management controls may have their temporary U.S. DOT registration revoked.

Performance and Registration Information Systems Management

This is a federal–state partnership that makes safe performance a requirement for obtaining and keeping commercial vehicle registration. PRISM links federal motor carrier safety records with the state's vehicle registration system. The U.S. DOT number of the carrier responsible for safety is identified at the vehicle level allowing the state to determine a carrier's safety fitness before issuing license plates. Safety performance is continuously monitored, and carriers prohibited by FMCSA from operating in interstate commerce may have their ability to register vehicles denied. PRISM plays a key role in FMCSA's effort to remove high-risk carriers from our highways.

Research and Technology

Legislation also provides direction for FMCSA to undertake research and technology programs to promote not only motor carrier safety but also operational efficiency, productivity, and security. The Motor Carrier Research and Technology Program, described in Section 4111 of SAFETEA-LU (as well as in prior legislation) authorized research and technology to improve "the safety and efficiency of commercial motor vehicles [49 U.S.C. 31108(a)(3)(C)]" and R&D "to advance innovative solutions to problems involving CMVand motor carrier safety, security, and efficiency" [49 U.S.C. 31108(b)(1)]. Section 4126, describing the CVISN, stated that the purpose of the program is to "(1) improve the safety and productivity of commercial vehicles and drivers; and (2) reduce costs associated with commercial vehicle operations and federal and state commercial vehicle regulatory requirements."

Waivers, Exemptions, and Pilot Programs

Although full compliance with the FMCSRs is a foundation of safe performance, there is a need for opportunities to test alternative approaches to achieving equivalent or better safety outcomes. Section 206(f) of the MCA of 1984 authorized U.S. DOT to waive any regulation issued under that section if the "waiver is not contrary to the public interest and is consistent with the safe operation of commercial motor vehicles" (98 Stat. at 2835). As interpreted by the federal courts, however, the agency had to prove before a waiver was granted that safety would not be adversely affected. That standard was impossible to meet. In Section 4007 of TEA-21 (112 Stat. 107, at 401), Congress therefore revised the standard to make it more practical. FMCSA can now provide relief in the form of a waiver (for up to 90 days) or an exemption (up to 2 years) from a regulation issued under the MCA of 1984 or the CMVSA of 1986. The agency must determine that the waiver or exemption is in the public interest and would likely achieve a level of safety that is equivalent to, or greater than, the level that would be achieved by complying with the regulation. TEA-21 also permits FHWA to conduct pilot programs to evaluate alternatives to regulations relating to motor carrier, CMV, and driver safety.

THE REGULATORY PROCESS

The informal rule-making process used by most federal agencies is described in the Administrative Procedure Act (5 U.S.C. 553). This statute, which has been extensively interpreted by the courts, governs the types of rule makings, the processes for publishing notices and accepting comments to rule-making dockets, and the types of external party communications in which an agency may engage at various points in the regulatory process.

MCSRs are promulgated under the notice-and-comment process, which is technically "informal rule making." ("Formal" rule making, used by ICC for economic regulations and still employed by some federal agencies, involves the development of standards on a case-by-case basis through hearings.)

When it develops a proposal for a new regulation, an agency must provide a comprehensive set of assessments of its potential benefits and costs. An executive order issued during the administration of President Carter, and later the MCA of 1984, required these assessments for proposed motor carrier safety regulations. The various executive orders currently in effect includes those described in the following sections.

Executive Order 12866 (Regulatory Planning and Review) and U.S. DOT Regulatory Policies and Procedures

Because of the strong congressional and public interest, some rule-making actions are considered significant for the purposes of Executive Order 12866 and U.S. DOT regulatory policies and procedures. A “significant” or “economically significant” action is defined as any action that may

1. Have an annual effect on the economy of $100 million or more or adversely affect in a material way the economy, a sector or the economy, productivity, competition, jobs, the environment, public health or safety, or state, local, or tribal governments or communities;
2. Create a serious inconsistency or otherwise interfere with an action taken or planned by another agency;
3. Materially alter the budgetary impact of entitlements, grants, user fees, or loan programs or the rights and obligations of recipients thereof; or
4. Raise novel legal or policy issues arising out of legal mandates, the president’s priorities, or the principles set for the in the executive order.

If a regulatory action meets the first criterion, it is considered “economically significant.” If it meets the other criteria, but not the first, it is considered “significant for noneconomic reasons.” The executive order requires the issuing agency to provide to the Office of Information and Regulatory Affairs (OIRA) of the Office of Management and Budget (OMB) “an assessment of the potential costs and benefits of the regulatory action” (*12*).

Regulatory Flexibility Act

To meet the requirements of the Regulatory Flexibility Act (5 U.S.C. 601-612), an agency is required to evaluate the effects of a rule-making action on small entities and make a preliminary determination whether a regulation arising from the proceeding would have a significant economic impact on a substantial number of small entities.

Executive Order 13132: Federalism

An agency must analyze a proposed rule-making action in accordance with the principles and criteria in Executive Order 13132: Federalism. The analysis is required to determine if a rule-making action is anticipated to have a substantial direct effect on states, whether it could limit the policy-making discretion of the states, and whether it might preempt any state law or regulation.

Executive Order 12988: Civil Justice Reform

Executive Order 12988: Civil Justice Reform directs agencies to formulate its rule makings in order to minimize litigation, eliminate ambiguity, and reduce their burden on regulated entities.

National Technology Transfer and Advancement Act

The National Technology Transfer and Advancement Act of 1995 (NTTAA), Public Law 104–113, Section 12(d) (15 U.S.C. 272), directs agencies to use voluntary consensus standards in regulatory activities unless doing so would be inconsistent with applicable law or otherwise impractical. Voluntary consensus standards are technical standards (e.g., materials specifications, test methods, sampling procedures, and business practices) that are developed or adopted by voluntary consensus standard bodies, such as SAE. NTTAA directs agencies to provide Congress explanations when they decide not to use available and applicable voluntary consensus standards.

Executive Order 13045: Protection of Children

An agency must analyze proposals under Executive Order 13045: Protection of Children from Environmental Health Risks and Safety Risks. The key issue is whether a proposed rule could present an environmental risk to health or safety that would disproportionately affect children.

Executive Order 12630: Taking of Private Property

This analysis is required to assess whether a proposed rule could constitute a taking of private property or otherwise have taking implications under Executive Order 12630: Governmental Actions and Interference with Constitutionally Protected Property Rights.

EFFECT ON OTHER REGULATIONS

Agencies must evaluate new regulatory proposals to determine their potential effect on other regulations.

Executive Order 12372: Intergovernmental Review

Executive Order 12372 directs agencies to perform an assessment to determine whether intergovernmental consultation on federal programs and activities would be required for a rule-making proposal.

Paperwork Reduction Act

OMB regulations implementing the act (5 CFR 1320: Controlling Paperwork Burdens on the Public), agencies must estimate the burden that new regulations would impose on regulated entities required to generate, maintain, retain, disclose, or provide information to or for the agency.

National Environmental Policy Act

The National Environmental Policy Act of 1969 (NEPA) (42 USC 4321–4347), other statutes, regulations (including those issued by the Council of Environmental Quality, 40 CFR 1500–

1508), Executive Orders, DOT Order 5610.1(c), and U.S. DOT agency orders (including those of FMCSA and FHWA) require that the agencies consider the environmental impacts of agency decisions. NEPA requires that an environmental impact statement (EIS) be prepared for “major federal actions significantly affecting the quality of the human environment.” If an action may or may not have a significant impact, the agency must prepare an environmental assessment (EA). Agencies must obtain public comment on a draft EIS before issuing a final EIS. Although there is no statutory requirement to obtain public comment on a draft EA, it is U.S. DOT’s policy to do so (*13*).

Energy Effects

Executive Order 13211 requires an analysis to determine whether a rule-making proposal would likely have a significant adverse effect on the supply, distribution, or use of energy. The administrator of the OIRA in OMB may designate certain rule makings as significant energy actions.

Unfunded Mandates

Agencies are required to determine whether a proposal or rule would impose a federal mandate resulting in the expenditure by state, local, and tribal governments, in the aggregate, or by the private sector, of $120.7 million or more in any 1 year (2 U.S.C. 1531 et seq.).

OTHER AGENCIES WITH TRUCK AND BUS SAFETY RESPONSIBILITIES

In addition to FMCSA, other agencies in the U.S. DOT exercise oversight responsibilities that contribute to truck and bus safety. FHWA is responsible for the Federal-Aid Highway System, upon which trucks and buses rely. NHTSA is responsible for setting and enforcing vehicle performance standards. PHMSA (until March 2005 part of the Research and Special Programs Administration) develops and promulgates regulations for safe transportation of hazmat, which are enforced by FMCSA.

Truck and bus drivers and their employers are also subject to regulations concerning workplace safety and wages, administered by agencies within the U. S. Department of Labor.

Vehicles and the Highway Infrastructure: FHWA

FHWA carries out the federal highway programs in partnership with the state and local agencies to meet the nation’s transportation needs. One of FHWA’s responsibilities regarding truck and bus safety is to foster nationwide uniformity of standards for signs, signals, designs, and safety features on major highway systems. The physical interrelationships between vehicles and highways are key elements to promote and ensure safety (*14*).

The relationship between the configuration, weights, and dimensions of CMVs and the highway environment has been a dynamic one. Early 20th-century roads were no match for the vehicle loads imposed by the burgeoning trucking industry. Furthermore, laws and regulations concerning vehicle weights and dimension varied widely from state to state. By 1941, the maximum gross load on one axle ranged from 12,000 lb (5,448 kg) to 24,640 lb (11,190 kg). In

May 1942, the Public Roads Administration (predecessor to the Bureau of Public Roads, later FHWA) and AASHO implemented a provisional uniform code of weights, heights, and lengths of motor vehicles. It allowed axle loads of 18,000 lb (8,172 kg), gross loads on four wheels of 30,000 lb (13,620 kg), and up to 40,000 lb (18,160 kg) on trucks of three or more axles (*15*).

Over the years, federal regulations on CMV weights and dimensions changed several times in response to demands for more consistent and heavier weights on the Interstate system, in part driven by rising fuel prices and the need to consider the effects of axle placements and the number of vehicle axles on infrastructure wear. The STAA of 1982 codified the federal regulation of vehicle length. It prohibited the states from establishing maximum trailer lengths of less than 48 ft for trailers used in a single-trailer combination or of less than 28 ft for trailers used in a double-trailer configuration, applicable to the national network (NN) (the Interstate system and other Federal-Aid Primary Highways). Overall vehicle length limits were prohibited on the NN (49 USC 31111), except for "specialized equipment" vehicles such as those used by automobile and boat transporters, which retained overall length limitations.

The Intermodal Surface Transportation Efficiency Act of 1991 (ISTEA) froze the weights of longer combination vehicles with two or more trailers operating above 80,000 lb (36,320 kg) on the Interstate system at the lawful weight limits in effect as of June 1, 1991 [23 USC 127(d)]. It also froze the maximum cargo-carrying length of combinations with two or more cargo-carrying units operating on the NN on the same date (49 U.S.C. 31112). The weight freeze, like other federal weight standards, is enforced through the withholding of certain Federal-Aid Highway funds. The length freeze is enforced through injunctive action in federal court (49 USC 31115) (*16*).

New Vehicle Standards: NHTSA

NHTSA sets and enforces safety performance standards for motor vehicles and motor vehicle equipment and, through grants to state and local governments, enables them to conduct effective local highway safety programs. NHTSA is responsible for reducing deaths, injuries, and economic losses resulting from motor vehicle crashes. This is accomplished in part by setting and enforcing safety performance standards for motor vehicles and motor vehicle equipment.

NHTSA investigates safety defects in motor vehicles; sets and enforces fuel economy standards; helps states and local communities reduce the threat of drunk drivers; promotes the use of safety belts, child safety seats, and air bags; investigates odometer fraud; establishes and enforces vehicle antitheft regulations; and provides consumer information on motor vehicle safety topics. NHTSA also conducts research on driver behavior and traffic safety to develop efficient and effective means of bringing about safety improvements (*8*).

Change in Delegation of Authority Between FMCSA and NHTSA

Section 101(f) of MCSIA provides that the Title 49 authority to promulgate safety standards for CMVs and equipment subsequent to initial manufacture be vested in the Secretary of Transportation and that this authority may be delegated. The Secretary delegated to the administrator of NHTSA the authority to promulgate safety standards for CMVs and equipment subsequent to initial manufacture when the standards are based upon and similar to a federal motor vehicle safety standard (FMVSS) promulgated under 49 USC 301. The NHTSA administrator may promulgate a standard simultaneously with the FMVSS on which it is based.

The authority to promulgate safety standards for CMVs and equipment subsequent to initial manufacture is delegated to the FMCSA administrator when the standards are not based on and similar to an FMVSS promulgated under 49 USC, Chapter 301 [49 CFR 1.50(n) and 1.73(g)] (*21*). In essence, the authority to require retrofitting of equipment on vehicles already in service is now delegated primarily to NHTSA. Prior to this change, FMCSA (or FHWA) had broader retrofit authority.

Occupational Safety: Occupational Safety and Health Administration

The Occupational Safety and Health Act (OSH Act) charges the Occupational Safety and Health Administration (OSHA) with the responsibility of ensuring, as extensively as possible, healthy working conditions for every working man and woman in the nation [Section 4(b)(1)] (*18*).

OSHA, however, is prohibited by Section 4(b)(1) of the OSH Act [29 USC 653(b)(1)] from enforcing its regulations if a working condition is regulated by another federal agency. For example, when CMVs and their drivers are operating on public highways, the DOT has jurisdiction. When workers are loading and unloading trucks, however, OSHA regulations govern the safety and health of those workers and the responsibilities of employers to ensure the workers' safety and health.

Section 405 of the STAA of 1982 (49 USC 31105) provides protection from reprisal by employers for truckers and certain other employees in the trucking industry involved in activity related to interstate CMV safety and health. OSHA's implementing regulations are codified at 29 CFR, Part 1978.

Wages: Employment Standards Administration of the U.S. Department of Labor

The authority of DOT does not extend to the computation of wages. The U.S. Department of Labor has this responsibility. So long as workers are paid at least the minimum hourly wage, the wages themselves may be computed on whatever basis the employer chooses. Some CMV drivers are paid on an hourly basis, while others are paid by the mile or by a percentage of the value of the cargo transported on a given run.

The Fair Labor Standards Act (FLSA) (29 USC 201–219) governs wages, including minimum wage rates and overtime pay. FLSA generally requires overtime pay for more than 40 h of work per week.

Section 13(b)(1) [29 USC 213(b)(1)] provides that the overtime requirements of Section 7 (29 USC 207) do not apply with respect to any employee for whom the Secretary of Transportation has power to establish qualifications and maximum HOS pursuant to the provisions of Section 204 of the MCA of 1935. The overtime provisions therefore do not cover drivers of CMVs operating in interstate commerce. Nonetheless, the minimum wage requirements of Section 6 (29 USC 206) apply to these drivers. The overtime exemption has been interpreted as applying to any driver, driver's helper, loader, or mechanic employed by a carrier and whose duties affect the safety of operation of motor vehicles in the transportation on public highways of passengers or property in interstate or foreign commerce. It also applies regardless of whether the employer is a private, common, or contract carrier of property or passengers (*19*).

RESEARCH NEEDS

Several statutory and administrative requirements govern reviews of existing regulations to determine whether they should be revised or revoked. Since 1979, the Regulatory Policies and Review Procedures of the U.S. DOT have required these reviews. Additional requirements are contained in Executive Order 12866: Regulatory Planning and Review and section 610 of the Regulatory Flexibility Act. The Section 610 reviews must be conducted on rules that have been published within the last 10 years and have a "significant economic impact on a substantial number of small business entities." Most U.S. DOT agencies have divided their regulations into 10 different groups and plan to analyze one group each year (*20*).

The knowledge bases of the physical sciences, medicine, engineering, and public policy are continually growing and changing. The safety regulations and programs that are built upon those foundations must also evolve.

The process of estimating the benefits and costs of regulations depends heavily upon the availability of current and comprehensive data on the characteristics of the regulated populations. In a large and dynamic environment like the motor carrier industry, obtaining this data is a considerable challenge.

Finally, a comprehensive and useful set of regulatory analyses hinges upon the development of well-reasoned estimates of the proposed regulation's benefits and costs to both the entities directly affected as well as to society as a whole. There is a continued need to develop and test new analytical tools.

ACKNOWLEDGMENTS

Many thanks to Charles Medalen of the FMCSA Office of Chief Counsel and David R. Miller and Larry W. Minor of the FMCSA Office of Policy and Program Development, who provided assistance in the legal research and comments on drafts of this chapter.

NOTE

1. *Sweatshops on Wheels: Winners and Losers in Trucking Deregulation* (Michael H. Belzer, Oxford University Press, 2000) provides an extensive discussion of the historical economic and safety regulation of the trucking industry.

REFERENCES

1. Locklin, D. P. *Economics of Transportation,* 7th ed. Richard D. Irwin, Inc., Homewood, Ill., 1972.
2. *Regulation of Transportation Agencies.* S. Document No. 152. 73rd Congress, 2nd Session. February 28, 1934.
3. 61 FR 57251. November 5, 1996 (except as specifically noted).
4. 1 FR 46 at 49. March 24, 1936.
5. Belzer, M. *Sweatshops on Wheels: Winners and Losers in Trucking Deregulation.* Oxford University Press, New York, 2000. p. 67.
6. History and Mission. NTSB. www.ntsb.gov/Abt_NTSB/history.htm. Accessed March 10, 2005.
7. About NHTSA: Who We Are and What We Do. www.nhtsa.dot.gov/. Accessed March 25, 2005.

8. ICC Motor Carrier Cases, Volume 1, Ex Parte MC-4. 1937. p. 1.
9. Motor Carrier Safety. TEA-21: A Summary. www.fhwa.dot.gov/tea21/sumsafe.htm#mcs. Accessed March 10, 2005.
10. 65 FR 70509. November 24, 2000.
11. 65 FR 58663. October 2, 2000.
12. U.S. General Accounting Office. *Regulatory Reform: Implementation of the Regulatory Review Executive Order*. Report GAO/T-GGD-96-185.
13. Eisner, N. *Rulemaking Requirements for Use in the Department of Transportation*. March 2000.
14. Who We Are and What We Do. FHWA, U.S. Department of Transportation. www.fhwa.dot.gov/whoweare/index.htm. Accessed March 11, 2005.
15. *America's Highways 1776–1976: A History of the Federal Aid Program.* FHWA, U.S. Department of Transportation.
16. *Federal Size Regulations for Commercial Motor Vehicles*. Publication FHWA-HOP-04-022. FHWA, U.S. Department of Transportation, October 2004.
17. 65 FR 41014. July 3, 2000.
18. Trucking Industry: OSHA Standards. U.S. Department of Labor. www.osha.gov/SLTC/trucking_industry/standards.html#Interpretations. Accessed March 13, 2005.
19. Fact Sheet #19. U.S. Department of Labor. www.dol.gov/esa/regs/compliance/whd/printpage.asp?REF=whdfs19.htm. Accessed March 13, 2005.
20. 69 FR 73494, at 73495, December 13, 2004. (Semiannual Regulatory Agenda).

APPENDIX A

A Chronology of Important Motor Carrier Safety Statutes

Refer to 49 USC, Chapters 5, 51, 59, 311, 313, and 315 (Source: S. Abbasi, FHWA, and C. Medalen, FMCSA)

1. Motor Carrier Act of 1935, 49 Stat. 546, ch. 498 (1935).
2. Department of Transportation Act, Pub. L. 89-670, 80 Stat. 931 (1966) (creation of U.S. DOT and transfer of certain motor carrier functions from the ICC to the department)).
3. The Hazardous Materials Transportation Act, Pub. L. 93-633, 88 Stat. 2156 (1975)
4. First Recodification, Pub. L. 95-473, 92 Stat. 1337 (1978).
5. Motor Carrier Act of 1980, Pub. L. 96-296, 30, 94 Stat. 793 (1980) (minimum levels of financial responsibility for motor carriers of property).
6. Bus Regulatory Reform Act of 1982, Pub. L. 97-261, 18, 96 Stat. 1102 (1982) (minimum levels of financial responsibility of motor carriers of passengers).
7. Surface Transportation Assistance Act of 1982, Pub. L. 97-424, 96 Stat. 2097 (1983)
8. Second Recodification, Pub. L. 97-449, 96 Stat. 2413 (1983).
9. Motor Carrier Safety Act of 1984, Pub. L. 98-554, Title II, 98 Stat. 2834 (1984).
10. Commercial Motor Vehicle Safety Act of 1986, Pub. L.99-570, Title XII, 100 Stat. 3207-170 (1986).
11. Truck and Bus Safety and Regulatory Reform Act of 1988, Pub. L. 100-690, Title IX, Subtitle B, 102 Stat. 4527 (1988).
12. Motor Carrier Safety Act of 1990, Pub. L. 101-500, 104 Stat. 1218 (1990).
13. Hazardous Materials Transportation Uniform Safety Act of 1990, Pub. L. 101-615, 104 Stat. 3244 (1990).
14. Omnibus Transportation Employee Testing Act of 1991 (Title V), Sec. 5, Pub. L. 102-143, 105 Stat. 952 (1991).

15. Intermodal Surface Transportation Efficiency Act of 1991; Motor Carrier Act of 1991, Title IV of Pub. L. 102-240, 105 Stat. 2140 (1991).
16. Intermodal Safe Container Transportation Act of 1992, Pub. L. 102-548, 106 Stat. 3646 (1992), as amended by Intermodal Safe Container Transportation Amendments Act of 1996, Pub. L. 104-291, Title II, 110 Stat. 3453 1996).
17. Codification of Certain U.S. Transportation Laws as Title 49, U.S.C., Subtitle VI of Pub. L. 103-272, 108 Stat. 745 (1994).
18. Hazardous Materials Transportation Authorization Act of 1994, Pub. L. 103-311, 108 Stat. 1673 (1994).
19. National Highway System Designation Act of 1995, Pub. L. 104-59, 109 Stat. 568 (1995) especially Secs. 312, 326, 342, 344-346.
20. ICC Termination Act of 1995, Pub. L. 104-88, 109 Stat. 803 (1995).
21. Codification of Transportation Laws, Pub. L. 104-287, 110 Stat. 3388 (1996).
22. Transportation Equity Act for the 21st Century, Pub. L. 105-178, 112 Stat. 107 (1998).
23. Motor Carrier Safety Improvement Act of 1999, Pub. L. 106-159, 113 Stat. 1748 (Dec. 9, 1999).
24. Safe, Accountable, Flexible, Efficient Transportation Equity Act: A Legacy for Users, Pub. L. 109-59, 119 Stat. 1144 (August 10, 2005).

Useful Resources

http://dms.dot.gov. U.S. DOT electronic Docket Management System (DMS). DMS is an electronic, image-based database in which all DOT docketed information is stored for easy research, and retrieval. A docket is an official public record. DOT publishes and stores online information about proposed and final regulations, copies of public comments on proposed rules, and related information in the DMS.

www.fhwa.dot.gov/legsregs/legislat.html. Legislation and regulations page of FHWA. Highway-related statutes, regulations, and legislation.

www.fmcsa.dot.gov. Home page of FMCSA. Click on “Rules and Regulations.” Links to regulations, regulatory guidance, federal register rule makings and notices from 1998 forward.

www.gpoaccess.gov/nara/index.html. Office of the Federal Register, National Archives and Records Administration. The U.S. Government Printing Office and the Office of the Federal Register, National Archives and Records Administration work closely to disseminate the official text of federal laws; presidential documents; administrative regulations and notices; and descriptions of federal organizations, programs and activities.

www.nhtsa.dot.gov. Home page for NHTSA. Click on the tab “Laws/Regulations.”

www.reginfo.gov/public/. RegInfo.gov is a U.S. government website produced by OMB and the General Services Administration.

http://thomas.loc.gov/home/abt_thom.html. U.S. legislative information online, including legislation, public laws, the Congressional Record, committee information, and historical documents.

Enforcement and Compliance

ANNE T. MCCARTT
STEPHEN F. CAMPBELL, SR.
STEPHEN A. KEPPLER
BRENDA M. LANTZ

Two agencies of the U.S. DOT and the states share responsibility for motor carrier safety. NHTSA sets standards for new truck equipment and has some jurisdiction over equipment standards for trucks currently on the road. The FMCSA oversees the safety of commercial vehicles in interstate commerce (vehicles operating across state lines). FMCSA regulations cover equipment, licensing, HOS, and vehicle inspection and maintenance; FMCSA and the states share responsibility for enforcing these rules. The responsibility for regulating and enforcing the safety of intrastate commercial vehicle travel (travel by trucks operating only with a single state's borders) resides with the states. In addition, the Pipeline and Hazardous Materials Safety Administration promulgates regulations concerning safe transportation of hazmat, including cargo tank manufacturing standards. FMCSA enforces these regulations for highway transportation.

This chapter describes the major enforcement and compliance programs of FMCSA and the states, recent trends in these programs, and key research issues. Although commercial vehicle enforcement and compliance activities also include general traffic enforcement initiatives directed at passenger vehicle drivers, this chapter focuses primarily on activities directed at interstate motor carriers and bus companies and commercial vehicle drivers and their vehicles.

PERTINENT REGULATORY HISTORY

The structure and safety of the truck and bus industries have been heavily influenced by a series of major federal statutes. Summarized below are some of the key statutes affecting commercial vehicle enforcement and compliance programs. The section on motor carrier safety laws and regulations provides a more extensive review of the history of motor carrier safety laws and regulations.

ICC (1887–1995), created by the Interstate Commerce Act of 1887, was the first independent federal agency or so-called fourth branch of government. The original mission of ICC was to regulate railroads to ensure fair rates and eliminate rate discrimination, and to regulate other aspects of common carriers. In 1935 Congress enacted the MCA, which gave authority to the ICC to regulate motor carriers and drivers involved in interstate commerce by controlling operating permits, approving trucking routes, and setting tariff rates. Between 1935 and 1980 there were few structural changes in the way that the federal government regulated the motor carrier industry. However, the enactment of the MCA of 1980 and other subsequent acts essentially deregulated the trucking industry in an effort to promote competition and increase efficiency.

The STAA of 1982 established funding for state motor carrier enforcement programs. As a result, MCSAP was created to reduce the number and severity of commercial vehicle crashes and hazmat incidents by substantially increasing the level, consistency, uniformity, and effectiveness of programs directed at identifying and correcting safety defects, driver deficiencies, and unsafe motor carrier practices. MCSAP is a federal-aid matching (80% federal, 20% state) program providing annual grants to states to enforce FMCSRs and federal HMR or compatible state regulations. It is the major mechanism by which commercial vehicle laws and regulations are enforced and monitored in the United States. The MCSA of 1984 had the effect of preempting all state regulations for interstate motor carriers. In addition, the Secretary of Transportation was directed to establish criteria for annual inspection of interstate motor carrier vehicles.

The intent of CMVSA of 1986 was to ensure that drivers of large trucks and buses were qualified to operate those vehicles, to remove unsafe and unqualified drivers, and to ensure that drivers had only a single driver's license and had passed knowledge and skills tests before obtaining that license. States retained the right to issue driver's licenses but also were required to meet minimum national standards when licensing commercial vehicle drivers. Prior to the act, it was believed that many drivers were operating motor vehicles that they were unqualified to drive. In addition, commercial drivers were able to obtain driver's licenses from more than one state so that traffic convictions could be spread across several driving records. This allowed drivers with problematic driving histories to continue to drive.

The goal of ISTEA was to develop a national intermodal transportation system that was economically and energy efficient and environmentally sound. Instead of focusing solely on highway transportation, ISTEA emphasized intermodalism, and the act included many provisions to remove barriers separating different transportation modes in statute and practice. ISTEA resulted in a sea change in the way business was conducted in the transportation sector. Flexibility, innovation, and collaboration became the new buzzwords for transportation planning and development. With $155 billion authorized in federal highway funding for fiscal years 1992–1997, the relationships among the federal government and states and localities was transformed in terms of funding transportation projects. ISTEA restructured the Federal-Aid Highway Program, the mechanism through which states and localities obtain funding for projects, amended metropolitan planning requirements, required statewide transportation planning to consider freight and goods movement, and required states to meet uniform vehicle registration and fuel tax reporting requirements.

Enacted in 1998, TEA-21 restructured the motor carrier safety program. Flexibility was provided for state grants by allowing investment in areas providing the greatest potential for crash reduction based on state circumstances. In addition, states were required to implement performance-based MCSAP programs by 2000. TEA-21 authorized $579 million for MCSAP over 6 years with set-asides of up to 5% for national safety priorities and border safety enforcement. The basic motor carrier act was strengthened with new enforcement tools, the elimination of loopholes that permitted unsafe practices, and encouragement of innovative regulatory approaches.

MCSIA of 1999 had a significant impact on the motor carrier safety program in North America. The act created a separate agency, FMCSA, within U.S. DOT; FMCSA was charged with improving truck and bus safety. The act increased resources at the federal, state, and local levels, and facilitated the promulgation of truck and bus safety regulations in furtherance of NAFTA to help harmonize the commercial vehicle safety regimes in Mexico, Canada, and the United States.

SAFETEA-LU

Enacted August 10, 2005, SAFETEA-LU authorized the federal surface transportation programs for highways, highway safety, and transit for 2005–2009. With guaranteed funding of $244.1 billion, SAFETEA-LU aims to improve safety, reduce traffic congestion, improve efficiency in freight movement, increase intermodal connectivity, protect the environment, and build a foundation for addressing future transportation needs. SAFETEA-LU focuses on transportation issues of national significance but also gives state and community decision makers more flexibility for meeting local transportation needs.

The TEA-21 ceiling for the "basic" MCSAP was $169 million. SAFETEA-LU increased the ceiling to $188 million in 2005 and to $209 million in 2009. The 2009 ceiling reflects a 24% increase from the TEA-21 ceiling. When the new state grant program funding allocations are considered, the total funding available to states will be significantly increased. Annual funding for other MCSAP grant programs includes $25 million for CDL; $32 million for border enforcement; $5 million in 2005 to $9 million in 2009 for PRISM; $25 million for CVISN; $2 million in 2005 to $3 million in 2009 for safety data improvement; and $5 million in 2005 to $9 million in 2009 for CDLIS. Total funding for MCSAP and its related programs increases from $282 million in 2005 to $308 million in 2009. Total administrative funding for FMCSA increased from $213 million in 2005 to $234 million in 2009.

MCSAP BASIC PROGRAM

When MCSAP was established in 1983, only 12 states had a commercial vehicle safety program that met the eligibility criteria for MCSAP funding. Today every state has at least the basic elements of a program. To receive basic program funds, a state must adopt and enforce state laws compatible with FMCSR and HMR; submit to FMCSA an annual commercial vehicle safety plan that reflects a performance-based program as specified; obligate the state share of 20%; and maintain a minimum level of effort. States with approved commercial vehicle safety programs receive basic program funds based on four equally weighted factors: road miles, total vehicle miles traveled, annual population estimates, and special fuel consumption (net after reciprocity adjustment). Additional incentive funds are available to states that show improvements in performance, based on measures involving fatal crashes involving large trucks, uploading inspection and crash data to FMCSA, and verifying CDLs during all roadside inspections. Funded program elements include roadside driver and vehicle inspections, traffic enforcement, motor carrier compliance reviews, public education and awareness, and data collection.

As noted earlier, under MCSAP, FMCSA provides matching (80% federal, 20% state) annual grants to states to enforce the FMCSR and HMR or compatible state regulations pertaining to CMV safety. As can be seen in Figure 1, the amount of MCSAP funds provided to states has grown steadily. It should be noted that in federal fiscal year 2001, an additional $55 million was made available through MCSIA of 1999. In addition, many states contribute much more than the minimum 20% matching requirement.

An important organization in commercial enforcement and compliance is the CVSA. Formally created in 1982, CVSA is a not-for-profit association of state, provincial, and federal officials responsible for the administrative and enforcement of motor carrier safety laws and

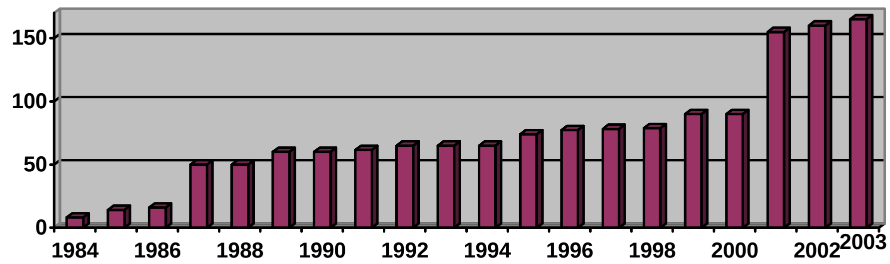

FIGURE 1 MCSAP allocations to states ($ millions), federal FY 1984–2003.

regulations in the United States, Canada, and Mexico. Its members include all U.S. states and territories, all Canadian provinces and territories, and the country of Mexico; these jurisdictions are represented by various DOTs, public utility and service commissions, state police, highway patrols, and ministries of transportation. There also are almost 500 associate members including truck and bus carriers, industry associations, insurance companies, safety product and service providers, commercial vehicle drivers, research organizations, manufacturers, and others. The mission of CVSA is to achieve uniformity, capability, and reciprocity of commercial vehicle inspections and other enforcement activities throughout North America. CVSA activities focus on developing motor carrier, driver, vehicle and cargo safety standards; conducting education, training, and enforcement programs; and holding conferences and meetings.

In addition to FMCSA, the state agencies that administer the MCSAP program, and CVSA, state and local law enforcement agencies and state driver licensing agencies are involved in various commercial vehicle enforcement and compliance activities.

MAJOR ENFORCEMENT AND COMPLIANCE PROGRAMS

Roadside Inspections

Roadside safety inspections of commercial vehicles and drivers are conducted by certified inspectors in accordance with the North American Standard Inspection Procedures and North American Standard Out-of-Service Criteria developed by CVSA, in cooperation with FMCSA (CVSA 2006a, 2006b). These standards allow for international uniform inspection procedures, including the identification of safety violations that are severe enough to place a vehicle, driver, or load out-of-service until the defect or condition is corrected. As indicated in Figure 2, there are six inspection levels. States conduct inspections at permanent inspection stations, mobile inspection locations, or a combination of the two.

According to data from MCMIS, maintained by FMCSA, 3,014,907 roadside inspections were conducted in 2004. This included 2,957,827 driver inspections, 2,249,338 vehicle inspections, and 178,951 hazmat inspections. The percentage of inspections with one or

Level I: North American Standard Inspection encompasses most complete examination of driver (e.g., driver's license, driver's record of duty status as required, hours of service, seat belt, alcohol and drugs) and vehicle (e.g., brake system, coupling devices, tires, hazardous materials if applicable).

Level II: Walk-around driver/vehicle inspection involves examination of driver and examination of vehicle without physically getting under the vehicle.

Level III: Roadside driver/credential only inspection.

Level IV: Special inspection typically involving one-time examination of a particular item, often conducted in support of a special study.

Level V: Vehicle-only inspection conducted without a driver present.

Level VI: Enhanced NAS inspection for radioactive shipments

FIGURE 2 Levels of roadside safety inspections.

violations was 73%. The percentage of inspections resulting in at least one violation was 36% for driver inspections, 69% for vehicle inspections, and 19% for hazmat inspections. The percentage of inspections with out-of-service violations was 7% for driver inspections (based on Level 1, 2, and 3 inspections), 23% for vehicle inspections (based on Level 1, 2, and 5 inspections), and 6% for hazmat inspections.

Table 1 summarizes roadside inspection activities for Levels 1–5 during calendar year 2004, based on MCMIS data.

For commercial buses in 2003, 24,637 roadside driver inspections and 35,584 vehicle inspections were conducted. The out-of-service rates were 6% for driver inspections and 10% for vehicle inspections.

TABLE 1 Roadside Inspection Activities in 2004

	Level 1: Full		**Level 2: Walk-Around**		**Level 3: Driver Only**		**Lev el 4: Special Study**		**Level 5: Terminal**	
	N	%	*N*	%	*N*	%	*N*	%	*N*	%
Inspections without violations	277,150	26	218,472	19	283,587	38	9,515	45	21,682	60
Inspections with violations	793,815	74	924,005	81	460,798	62	11,669	55	14,214	40
Total inspections	1,070,965	100	1,142,477	100	744,385	100	21,184	100	35,896	100

The inspections and violation rates do not necessarily reflect the state of the entire industry, because inspectors use various methods to select higher-risk vehicles and drivers for inspection. In many instances vehicles and trucks may be randomly selected, but there are tools available to inspectors that are intended to identify high-risk carriers for possible inspection. The Inspection Selection System (ISS) is the primary tool used on a laptop computer at the roadside to screen motor carrier vehicles and determine the usefulness of conducting a roadside inspection. ISS returns a motor carrier snapshot with several safety performance indicators. ISS is linked to ASPEN, the driver–vehicle inspection software used by most states and FMCSA. ASPEN permits recording information on the inspection, e.g., auto-populating the carrier name and address data fields; printing the inspection report; and electronic transmission of inspection data to national data systems. ISS uses a local database that is refreshed weekly via the Safety and Fitness Electronic Records (SAFER) System, and it also can be used as an online query tool.

The most recent information on inspection results for a representative sample of trucks and drivers comes from the 1996 National Fleet Safety survey (OMC, 1997). This survey estimated overall, driver- and vehicle-specific out-of-service rates for the general population of CMVs on the road and for the subpopulation of trucks carrying hazmat, based on data collected in 11 states from more than 10,000 random Level 1 truck inspections. The estimated national out-of-service rates were 32% overall, 29% for vehicles, and 5% for drivers. These rates were slightly but significantly lower than the rates obtained from 1996 MCSAP inspection data. For trucks carrying hazmat, the overall out-of-service rate was 27%, with vehicle and driver rates of 25% and 4%, respectively. For all trucks and for hazmat trucks, about half of the out-of-service-related violations were brake related.

Traffic Enforcement

Traffic enforcement is a component of the MCSAP. An inspection is identified as a Traffic Enforcement Inspection when at least one traffic violation other than an alcohol- or drug-related violation is present during the inspection, and traffic enforcement actions that initiate a subsequent roadside inspection are included in the MCSAP program. Traffic enforcement actions for commercial vehicle drivers are based on 21 violations (Figure 3), including moving violations of a serious nature (e.g., following too close, speeding, reckless driving), violations related to the use or possession of alcohol or drugs, alcohol- or drug-related violations related to use or possession, specific other traffic violations (e.g., size and weight violations, failure to use hazard warning flashers), and unspecified other traffic violations.

In the SAFETEA-LU legislation, a provision was included to permit traffic enforcement to occur on commercial vehicle operators and non-commercial vehicle operators without an inspection being conducted.

On the basis of information from the MCMIS system, in 2004 there were 803,032 inspections attributed to traffic enforcement. This was 27% of roadside inspections conducted in 2004. The percentage of inspections that resulted in out-of-service determinations was 8.5% for driver inspections and 26% for vehicle inspections. From 2001 to 2004 there was a steady increase in the amount of traffic enforcement activity, in large part due to a stronger focus on the driver.

Specified Violations Includes violations that are a result of serious traffic violations (moving and drug and alcohol violations) and other traffic violations.

Serious Moving Violation Moving violations of a serious nature:

1. 392.2FC: Following too closely,
2. 392.2LC: Improper lane changing,
3. 392.2R: Reckless driving,
4. 392.2S: Speeding,
5. 392.2C: Failure to obey traffic control device,
6. 392.2P: Improper passing,
7. 392.2T: Improper turns, and
8. 392.2Y: Failure to yield right of way.

Alcohol or Drug Related Violation Violations relating to use or possession of drugs or alcohol:

9. 392.4 and 392.4A: Driver uses or is in possession of drugs and
10. 392.5 and 392.5A: Driver uses or is in possession of alcohol.

Other Traffic Violations Violations that occur regardless of the vehicle moving:

11. 392.20: Failing to secure parked vehicle properly,
12. 392.21: Stopped vehicle interfering with traffic.
13. 392.22A: Failing to use hazard warning flashers,
14. 392.22B: Failing/improper placement of warning devices, and
15. 392.2W: Size and weight.

Unspecified Traffic Violations All other violations:

16. 392.2: General/unspecified and
17. 392.2OT: Other moving violations

FIGURE 3 Twenty-one driver violations.

Compliance Reviews

Compliance reviews (CRs), conducted by federal and state enforcement staff, are a primary means to monitor the safety of the motor carrier industry and the only tool for assigning safety fitness ratings to carriers (49 USC 31144). Adherence to federal laws and regulations is used as the primary indicator of a carrier's safety posture. Most CRs are conducted as a result of information obtained from SafeStat, complaints considered legitimate, crash investigations, carrier requests or follow-ups to earlier reviews or enforcement action. CRs may result in the initiation of enforcement actions. It is intended that through education, heightened safety regulation awareness, and enforcement effects of the CR, motor carriers will improve the safety of their commercial vehicle operations and, ultimately, reduce their crash involvement.

Conducted on-site at a carrier's primary place of business, CRs encompass an examination of a motor carrier's records and operations to determine whether adequate safety management controls are in place to ensure acceptable compliance with federal safety (primarily 49 CFR, Parts 300–399) and HMRs (primarily 49 CFR, Parts 171–180). During the review, the carrier also receives education on safety regulations and the carrier's responsibilities. Carriers are assigned a safety rating (satisfactory, conditional, unsatisfactory) based on six factors (49 CFR, Part 385). An unsatisfactory rating general results in a warning letter, a fine or other civil penalty, or out-of-service placement. Although most enforcement actions are of a civil nature, in some instances criminal prosecution ensues from egregious violations. CRs do not assess the safety fitness of employees of a carrier, including drivers.

CRs require considerable resources, typically 3 to 4 days of an investigator's time. On the basis of data obtained from the MCMIS system (Table 2), 7,623 individual interstate carriers underwent CRs in 2004; during 1999–2004, the number of carriers reviewed ranged from fewer than 7,000 to about 10,000. The number of CRs in a given year represents only a small proportion of active interstate motor carriers, estimated at more than 675,000 in 2004. On the basis of the CRs conducted in 2004, 58% of carriers received a satisfactory safety rating, 30% received a conditional rating, and 9% were rated unsatisfactory. The remaining 3% were not rated.

It should be noted that other types of carrier reviews conducted include security reviews, reviews of shippers of hazmat, and reviews of cargo tank manufacturers and repair facilities.

In view of the relatively resource-intensive requirements of CRs and the fact that only a small proportion of carriers is subject to reviews in a given year, FMCSA is considering alternative approaches to monitoring and evaluating motor carrier safety. The Comprehensive Safety Analysis 2010 Program is directed at conducting this investigation and helping FMCSA direct these activities for the future.

Security Sensitivity Visits

In response to concerns about potential terrorist threats to the transportation industry, FMCSA began a program to conduct on-site visits to hazmat to raise awareness of potential threats, identify security vulnerabilities, and identify potential security programs and countermeasures. These security-sensitivity visits also include a review of carrier records to identify any suspicious activities by carrier employees that could affect security. FMCSA has targeted carriers transporting hazmat in types and quantities that terrorists could use as weapons. In addition, safety investigators have visited companies that train truck drivers or lease trucks and drivers, high-risk facilities (e.g., chemical plants), hazmat shippers, and other operations determined to be at risk. As of January 31, 2002, 36,246 contacts had been completed, resulting in 280 findings of suspicious activities with 126 referrals reported to the Federal Bureau of Investigation (FMCSA, 2002).

TABLE 2 Carrier Ratings Based on Compliance Review, 2004

	Percent (*N* = 7,623)
Satisfactory	58
Conditional	30
Unsatisfactory	9
Not rated	3

New Entrant Motor Carrier Program

An estimated 40,000–50,000 new motor carriers begin operating each year. Research has found that new motor carriers have lower rates of compliance with federal regulations than established carriers, although the findings have differed with regard to the association between crash rates and carrier age (Corsi and Fanara, 1988; OMC, 1999). The new entrant motor carrier program was developed in response to a congressional requirement that FMCSA establish minimum requirements for new motor carriers seeking federal interstate operating authority.

Effective January 1, 2003, all new entrant motor carriers, including private and for-hire carriers, operating in interstate commerce must register with FMCSA and are thereafter subject to an 18-month safety monitoring or probationary period. At the end of this period carriers may receive permanent U.S. DOT registration if they have fulfilled several requirements. Carriers are required to pass a safety audit of their safety systems or pass (i.e., not be deemed "unfit") a compliance review; maintain safe operations, based on roadside inspection and crash records; certify that they have a system to ensure compliance with regulations, and not have any outstanding civil penalties to receive permanent U.S. DOT registration. The safety audit, conducted by state or federal auditors, examines the carrier's safety management system. Areas of review will include driver qualifications and duty records, vehicle maintenance, crash register, and controlled substances and alcohol use and testing requirements.

New entrant motor carriers that fail to maintain adequate basic safety management controls may have their temporary U.S. DOT registration revoked. The program provides that most safety audits will be conducted on-site at the carrier's primary place of business approximately 3 to 6 months after registration. Safety audits are conducted primarily by federal and state personnel; private contractors are also used in some locations.

Alcohol and Drug Testing

Federal safety regulations (49 CFR, Part 382) require carriers to test all commercial drivers for drugs before employment (if the driver has not recently been in a drug and alcohol testing program). Carriers must test for both alcohol and drugs after crashes, and if a driver is suspected by a supervisor of using drugs or alcohol while at work. Random testing requirements specify that carriers must randomly test 10% of their CDL drivers for alcohol and 50% of their drivers for a specified set of controlled substances each year. In this testing, a driver with blood alcohol content (BAC) at or above 0.02% is not permitted to perform safety-sensitive functions for at least 24 h. Drivers with BACs of 0.04% or above must be evaluated by a substance abuse professional and undergo additional testing before being allowed to return to duty. Drivers are tested for marijuana, cocaine, opiates, amphetamines, and PCP; cutoff levels are specified for determined violations. New alcohol test rules were issued in 1994 that place drivers out of service if they are found with any alcohol (BAC at or above 0.02%) in their systems.

On the basis of information from the FARS, 4% of fatally injured large truck drivers had BACs at or above 0.08%, the per se alcohol-impaired limit in all states; this percentage has fallen since 1982, when it was 17%. In contrast, 32% of passenger vehicle drivers in 2004 had a BAC at or above 0.08% (IIHS, 2005). A 1995 roadside study in four states found that almost 5% of truck drivers tested positive for illicit drug use but only 0.2% tested positive for alcohol (FHWA, 1995).

Each year, FMCSA estimates drug and alcohol use rates for CDL drivers, on the basis of a statistical sample of test information collected from motor carriers. In 2003, it estimated that 2% of drivers with CDLs used controlled substances and 0.2% used alcohol (BAC at or above 0.04%). For the 2003 survey, 4,934 carriers were asked to provide testing information; of these carriers 1,318 (27%) provided data for controlled substance random testing and 1,132 (23%) provided data for random alcohol testing (FMCSA, 2005b). The most recent FMCSA data available on postcrash testing indicate that in 1999, 2.6% of drivers involved in a nonfatal crash tested positive for illicit drugs (FMCSA, 2000b).

Commercial Driver's License

CMVSA of 1986 established minimum national standards that states must meet when licensing commercial vehicle drivers, made it illegal for commercial vehicle drivers to hold more than one license, and required states to adopt testing and licensing standards. Previously, the qualifications for receiving a CDL varied widely among the states. The CDL program places requirements on the commercial vehicle driver, motor carriers, and the states. Since April 1, 1992, drivers have been required to have a CDL in order to drive a CMV. More than 8 million drivers have passed the knowledge and skills tests and obtained a CDL. During the time period from April 1992 to June 1996, approximately 11% of CDL holders were disqualified at least once (FMCSA, www.fmcsa.dot.gov/safetyprogras/cdl.htm, November 25, 2003).

FMCSA issues standards for testing and licensing commercial vehicle drivers. The testing and licensing functions are administered by the individual states. The standards require drivers to pass knowledge and skills tests. Operators of certain types of commercial vehicles (e.g., tank vehicle, double or triple trailer) must pass additional tests. States' tests must be at least as stringent as the federal standards for the tests. Other states, employers, training facilities, governmental department and agencies, and private institutions can serve as third-party testers for a state if the tests are the same as those given by the state and the examiners meet the same qualifications as state examiners and other guidelines are met. States may grandfather drivers from the skills test provided they meet the definition of a good driving record and previously passed an acceptable skills test or have a good driving record in combination with certain driving experience. Federal law also specifies the information on the CDL.

Drivers and employers are subject to civil penalties and in aggravated cases, criminal penalties. States must be connected to CDLIS and the National Driver Register (NDR) to exchange information about commercial vehicle drivers and traffic convictions and disqualifications. A state uses both CDLIS and NDR to check a driver's record and CDLIS to make certain the applicant doesn't already have a CDL. Employing motor carriers also have access to certain information contained in CDLIS.

Within 30 days of a conviction for any traffic violation except parking, a driver must notify the employer, regardless of the type of violation or vehicle driven at the time. If a driver's license is suspended, revoked, or canceled or if the driver is disqualified from driving, the employer must be notified. Employers may not knowingly use a driver who has more than one license or whose license is suspended, revoked, canceled, or disqualified.

MCSIA of 1999 significantly strengthened the CDL program by enacting more than 20 new requirements. Provisions in the regulation address disqualification for driving while suspended, disqualified, or causing a fatality; emergency disqualification of drivers posing an imminent hazard; expanded definition of serious traffic violations; extended driver records check; new notification requirements; masking prohibition; and disqualification for violations obtained while driving a noncommercial motor vehicle. The act also requires FMCSA to withhold federal funding from the states if they do not comply with the regulations.

DATA SYSTEMS TO SUPPORT ENFORCEMENT AND COMPLIANCE ACTIVITIES

Over the past 10 years, FMCSA and the states have developed a number of databases and systems to support enforcement and compliance efforts; the key databases and systems are listed in Figure 4. The types of systems include the following:

- Centralized systems accessed via the Internet or FMCSA intranets,
- Distributed systems with laptop or desktop applications, and
- Data provided by state MCSAPs or driver licensing agencies, FMCSA, carriers, and others.

CDLIS Clearinghouse and NDR: Systems maintained by FMCSA and NHTSA to allow states' retrieval of license status or conviction history from state driver history records.

CVISN: FMCSA collection of information systems and networks to support commercial vehicle operations.

Enforcement Management Information System: Web-based application (emis.fmcsa.dot.gov) used to monitor, track, and store information related to FMCSA enforcement actions; authoritative source for FMCSA enforcement data.

ISS: FMCSA system used at roadside inspections to retrieve carrier performance indicators as tool to determine usefulness of conducting an inspection.

MCMIS: FMCSA warehouse and information system that captures data from field offices through SAFETYNET and other sources on inspections, crashes, compliance reviews, safety audits, and vehicle registrations.

National Law Enforcement Telecommunication System: Network operated and controlled by the states to link local, state, and federal agencies to exchange criminal justice and public safety information.

PRISM: FMCSA system linking federal carrier safety records with state vehicle registration systems.

SAFER: FMCSA website (www.safersys.org) displaying carrier information available to public, store and forward mailbox system, secondary databases, and communication links.

SafeStat (Safety Status Measurement System): FMCSA analysis system using information from compliance reviews to develop relative safety status and other information on interstate motor carriers.

SAFETYNET: FMCSA database management client–server system of data from driver–vehicle inspections crashes, compliance reviews, assignments and complaints.

FIGURE 4 Data systems to support commercial vehicle enforcement and compliance programs.

These systems gather, manage, and analyze data collected from state MCSAP, carriers, driver licensing agencies, and others. Despite FMCSA efforts to improve the completeness and accuracy of the data in these systems through MCSAP requirements and other means, deficiencies in this regard have been noted in audits of these systems regarding their usefulness in assessing the safety records of particular carriers or drivers and assessing the effectiveness of enforcement and compliance efforts (GAO, 2005; Campbell et al., 2004).

The SAFER system offers access to motor carrier safety data and related services to industry and the public over the Internet. Users can search FMCSA databases, register for a U.S. DOT number, pay fines online, order company safety profiles, challenge FMCSA data using the Data Qs system, access the Hazardous Material Route registry, obtain national crash and out-of-service rates for Hazmat Permit Registration, get printable registration forms, and find information about other FMCSA information systems. SAFER is the FMCSA communications nexus with links to various federal and state databases. It handles user queries, database refreshes, and inbound data transfers. SAFER consists of a website, store and forward mailbox system, secondary databases, and communication links.

SAFETYNET is an automated information management system designed to manage and provide appropriate access to crash data, roadside inspection history and data, and motor carrier and shipper identification information. This supports federal and state motor carrier safety programs by allowing the safety performance of interstate and intrastate commercial motor carriers to be monitored. To do this, SAFETYNET maintains records that include, but are not limited to, truck–bus driver name, Social Security number, license number, and date of birth, and truck–bus driver and company contact information, and vehicle identification numbers. FMCSA receives these data from designated state officials, either directly into SAFETYNET through paper forms that state data entry representatives enter into the system or through electronic data upload directly into SAFETYNET.

FMCSA operates and maintains MCMIS, the national data warehouse and information system that captures state-level data from SAFETYNET and other sources. MCMIS is web based and contains information on the safety fitness of commercial motor carriers and hazmat shippers subject to FMCSR and HMR.

RESEARCH TOPICS

A number of enforcement and compliance topics have been the subject of research over the years. The following highlights a few of these topics and provides examples of research addressing these topics.

Some studies have focused on issues related to the implementation, effectiveness, or efficiency of various enforcement programs. FMCSA studies, for example, have examined the effectiveness of the CDL program and limitations in some states' systems (FMCSA, 2000a; TML, 1998). Studies also have focused on the development of the CDL knowledge and skills test (Brock et al., 2005). Recent research has focused on the potential use of intelligent transportation system (ITS) and other technologies in commercial vehicle operations, enforcement, and monitoring (Conway, 2005; Freund and Kreeb, 2005; Shaffer and Loy, 2005).

Many studies have focused on various aspects of the HOS rules, including the extent of compliance; driver and schedule factors associated with violations; driver attitudes toward the rules and rule changes; and effects of the rule violations on fatigue-related driving. These studies have reported findings from surveys of long-distance truck drivers (Beilock, 1995, 2003; Belzer, 2000; Braver et al., 1992; McCartt et al., 1997, 2000, 2005) or motor carriers (Dick et al., 2006; FMCSA, 2005a). To support the development of effective HOS rules, studies also have focused on the relationship between elements of the HOS rules and crash risk (Jovanis et al., 2005) or the effects of work variables such as consecutive hours of driving on crash risk (Jones and Stein, 1987). Studies attempting to quantify the economic and safety impacts of the HOS rules have been conducted as part of FMCSA's rule-making activities (Campbell and Belzer, 2000; FMCSA and ICF Consulting, Inc., 2005).

Another active area of research has focused on identifying high-risk drivers or carriers on the basis of traffic or commercial vehicle inspection enforcement actions or crash involvements (Murray et al., 2006; Moses and Savage, 1996) or on developing tools to assist enforcement personnel in focusing on these drivers or carriers. Recent analyses have focused on developing a driver safety history indicator and incorporating the indicator into ISS (Lantz and Loftus, 2005). Studies differ on the effectiveness of SafeStat in successfully identifying high-risk carriers (Madsen and Wright, 1998; Volpe National Transportation Systems Center, 2004; Campbell et al., 2004). An audit by the Office of the Inspector General of U.S. DOT (2004) faulted the timeliness, accuracy, and completeness of data used in SafeStat and the algorithms used to identify high-risk carriers, and other researchers have pointed out limitations of MCMIS data reported by states (Blower and Matteson, 2003). Other research related to inspections has focused on the development and testing of ISS (Lantz et al., 1996); evaluating different inspection selection methods (Lantz, 1996); training safety inspectors (Tanner et al., 2005); associations of vehicle out-of-service criteria with crash reductions (Lentz and Allanach, 1992; Patten et al., 1989) and carrier out-of-service performance with compliance review ratings (Lentz et al., 1992); and the efficiency of out-of-service criteria as crash deterrents (Douglass et al., 1992). Research also has been directed at the relationship of carrier safety audits to safety performance (Moses and Savage, 1992).

Some state-based studies have examined various aspects of commercial vehicle enforcement programs. For example, Hughes addressed the quantification of the crash reduction benefits of "targeted" commercial vehicle enforcement efforts in North Carolina. McCartt et al. (1999) examined driver, carrier, vehicle, and other variables related to out-of-service determinations at inspections in New York State. In Massachusetts, Fijol (2003) examined the commercial vehicle DOT number match rates for crash and inspection data.

TRENDS IN ENFORCEMENT AND COMPLIANCE PROGRAMS AND NEW RESEARCH AREAS

In part due to congressional directives, over the past decade FMCSA has sought to redirect and focus its enforcement and compliance programs to achieve greater efficiencies (i.e., maximum results per resource expended) and effectiveness through the following:

- Identifying and focusing on problematic carriers and drivers (i.e., those with relatively poor safety records);
- Developing data-driven programs;
- Building databases to support problem identification, developing, monitoring, and evaluating programs, conducting enforcement, and research and analysis;

- Increasing oversight of new drivers and carriers; and
- Increasing the security of goods moved by commercial vehicles.

There will likely be more use of technologies in all aspects of commercial vehicle operations and enforcement and compliance programs, accompanied by a need to assess the implementation and effects of such use on enforcement, compliance, and safety:

- Electronic screening–bypass systems allowing qualifying carriers, vehicles, and drivers to bypass weigh stations, port-of-entry facilities, and possibly roadside inspections;
- Virtual inspection sites—many states are diversifying and providing increased mobility for their inspection force to better target high-risk operators;
- Electronic citation systems at roadside inspections and traffic stops;
- Electronic onboard recorders to monitor drivers' driving, on-duty and off-duty time;
- Wireless communication systems to evaluate driver, vehicle, cargo, and carrier performance and determine the need to inspect/scrutinize further;
- Driver license biometric identification technologies; and
- Automated vehicle performance monitoring (i.e., brakes, tires).

Summaries of FMCSA programs and data on current enforcement activities were based on information found on the FMCSA website, www.fmcsa.dot.gov, or http://ai.volpe.dot.gov/.

REFERENCES

Beilock, R. Schedule-Induced Hours-of-Service and Speed Limit Violations among Tractor-Trailer Drivers. *Accident Analysis and Prevention*, Vol. 27, 1995, pp. 33–42.

Beilock, R. Schedule Tightness Among Tractor-Trailer Drivers. *Traffic Injury Prevention*, Vol. 4, 2003, pp. 105–112.

Beilock, R., and R. B. Capelle. Economic Pressure, Long Distance Trucking, and Safety. *Journal of Transportation Research Forum*, Vol. 28, 1987, pp. 177–185.

Belzer, M. H. *Sweatshops on Wheels: Winners and Losers in Trucking Deregulation*. Oxford University Press, New York, N.Y., 2000.

Blower, D., and A. Matteson. Patterns of MCMIS Crash File Underreporting in Ohio. University of Michigan Transportation Research Institute, Ann Arbor.

Braver, E.R., C. W. Preusser, D. F. Preusser, H. M. Baum, R. Beilock, and R. Ulmer. Long Hours and Fatigue: A Survey of Tractor-Trailer Drivers. *Journal of Public Health Policy*, Vol. 13, 1992, pp. 341–366.

Brock, J. F., G. Golembiewski, J. McFann, K. Lewis, and B. Robinson. Development of the 2005 CDL Knowledge and Skills Test. Proc., 2005 International Truck and Bus Safety and Security Symposium, Alexandria, Va., 2005.

Campbell, K. L., and M. H. Belzer. Hours of Service Regulatory Evaluation Analytical Support, Task 1: Baseline Risk Estimates and Carrier Experience. Report No. UMTRI-2000-11. University of Michigan Transportation Research Institute, Ann Arbor, 2000.

Campbell, K., R. Schmoyer, and H.-L. Hwang. Review of the Motor Carrier Status Measurement System (SafeStat). Center for Transportation Analysis, Oak Ridge National Laboratory, Oak Ridge, Tenn., 2004.

Conway, A. J., and C. M. Walton. Potential Application of ITS Technologies to Improve Commercial Vehicle Operations, Enforcement, and Monitoring. Presented at 84th Annual Meeting of the Transportation Research Board, Washington, D.C., 2005.

Corsi, T. M., and P. Fanara. Deregulation, New Entrants, and the Safety Learning Curve. *Journal of the Transportation Research Forum,* Vol. 24, No. 1, 1988, pp. 3–8.

CVSA. *CVSA Operations Guide*. Commercial Vehicle Safety Alliance, Washington, D.C., 2006a.

CVSA. *North American Standard Out-of-Service Criteria: Handbook and Out-of-Service Pictorial Edition*. Commercial Vehicle Safety Alliance, Washington, D.C., 2006b.

Dick, V., J. Hendrix, and R. R. Knipling. New Hours-of-Service Rules: Trucking Industry Reactions and Safety Outcomes. In *Transportation Research Record: Journal of the Transportation Research Board, No. 1966*, Transportation Research Board of the National Academies, Washington, D.C., 2006, pp. 103–109.

Douglass, J. B., T. R. Miller, and G. M. Lentz. The Relative Efficiency of Out-of-Service Criteria as Accident Deterrents. Presented at 71st Annual Meeting of the Transportation Research Board, Washington, D.C., 1992.

FHWA. Random Roadside Drug and Alcohol Pilot Program: Final Report. FHWA, U.S. Department of Transportation, 1995

FMCSA. Evaluating Commercial Driver's License Program Vulnerabilities: A Study of the States of Illinois and Florida: Final Report. FMCSA, U.S. Department of Transportation, 2000a.

FMCSA. Results from the 1999 Drug and Alcohol Testing Survey. FMCSA, U.S. Department of Transportation, 2000b. www.fmcsa.dot.gov/Pdfs/mcsfe99.pdf.

FMCSA. Report on FMCSA's Security Sensitivity Visits to the House and Senate Committees on Appropriations: Status and Results of Security Sensitive Visits. FMCSA, U.S. Department of Transportation, January 31, 2002.

FMCSA Field HOS Survey: Motor Carrier Industry Implementation and Use of the April 2003 Hours-of-Service Regulations. FMCSA, U.S. Department of Transportation, 2005a.

FMCSA. Drug and Alcohol Testing Survey: 2003 Results. Analysis Brief No. FMCSA-RI-05-034. FMCSA, U.S. Department of Transportation, 2005b. www.fmcsa.dot/facts-research/briefs/drug-testing-update-2003.htm.

FMCSA and ICF Consulting, Inc. Regulatory Impact Analysis and Small Business Impact Analysis for Hours-of-Service Options. Report no. FMCSA-2004-19608-2094. FMCSA, U.S. Department of Transportation, August 15, 2005.

Fijol, R. State of the Practice: Commercial Vehicle DOT Number Match Rates for Crash and Inspection Data. Massachusetts Traffic Safety Research Program, University of Massachusetts, Amherst, 2003.

Freund, D., and R. Kreeb. Commercial Vehicle Safety Technology Diagnostics and Performance Enhancement: Tires and Brakes. Proc., 2005 International Truck and Bus Safety and Security Symposium, Alexandria, Va., 2005.

GAO. Large Truck Safety: Federal Enforcement Efforts Have Been Stronger Since 2000, But Oversight of State Grants Needs Improvement. Report No. GAO-06-156. General Accounting Office, December 2005. Available at www.gao.gov/cgi-bin/getrpt?GAO-06-156.

Gruberg, R. National Fleet Safety Survey, 1996: Final Analysis Report. Report No. FHWA-MC-98-015. U.S. Office of Motor Carriers, U.S. Department of Transportation, 1997.

Hughes, R. G. The Effectiveness of Commercial Motor Vehicle Enforcement in Reducing Truck-Involved Crashes. Highway Safety Research Center, University of North Carolina at Chapel Hill. Available at http://www.hsrc.unc.edu/pdf/hfactors/pdf/risk_mov_violation.pdf.

IIHS. Q&A: Large Trucks. Insurance Institute for Highway Safety, 2005. www.iihs.org/research/qanda/trucks.html.

Jones, I. S., and H.S. Stein. Effect of Driver Hours of Service on Tractor-Trailer Crash Involvement. Insurance Institute for Highway Safety, Arlington, Va., 1987.

Jovanis, P. P., S.-W. Park, K.-Y. Chen, and F. Gross. On the Relationship of Crash Risk and Driver Hours of Service. Proc., 2005 International Truck and Bus Safety and Security Symposium, Alexandria, Va., 2005.

Lantz, B. M. Evaluation of the Differences Between Spontaneous and Anticipated Roadside Inspections of Motor Carriers. Presented at 75th Annual Meeting of the Transportation Research Board, Washington, D.C., 1996.

Lantz, B. M., M. W. Blevins, and T. J. Hillegass. Development and Testing of a Roadside Inspection Selection System for Commercial Vehicles. Presented at 75th Annual Meeting of the Transportation Research Board, Washington, D.C., 1996.

Lantz, B., and J. Loftus. Development and Implementation of Driver Safety History Indicator into Roadside Inspection Selection System. *Transportation Research Record: Journal of the Transportation Research Board, No. 1969*, Transportation Research Board of the National Academies, Washington, D.C., 2006, pp. 121–125.

Lentz, G. M., and C. Allanach. Motor Carrier Accident Reduction Attributable to the Vehicle Out-of-Service Criteria. Presented at 71st Annual Meeting of the Transportation Research Board, Washington, D.C., 1992.

Lentz, G. M., T. M. Corsi, and P. Fanara. Carrier Vehicle Out-of-Service Performance and Safety/Compliance Review Rating: Statistical Relationships and Associated Policy Issues. Presented at 71st Annual Meeting of the Transportation Research Board, Washington, D.C., 1992.

Madsen, D. G., and D. G. Wright. Effectiveness Analysis of SafeStat. *Transportation Research Record: Journal of the Transportation Research Board, No. 1686*, TRB, National Research Council, Washington, D.C., 1999, pp. 8–12.

McCartt, A. T., M. C. Hammer, and S. Z. Fuller. Work and Sleep/Rest Factors Associated with Driving While Drowsy Experiences Among Long-Distance Truck Drivers. Proc., 41st Annual AAAM, 1997, pp. 95–108.

McCartt, A. T., L. A. Hellinga, and M. G. Solomon. Work Schedules Before and After 2004 Hours-of-Service Rule Change and Predictors of Reported Rule Violations in 2004: Survey of Long-Distance Truck Drivers. Proc., 2005 International Truck and Bus Safety and Security Symposium, Alexandria, Va., 2005.

McCartt, A. T., J. W. Rohrbaugh, M. C. Hammer, and S. Z. Fuller. Factors Associated with Falling Asleep at the Wheel Among Long-Distance Truck Drivers. *Accident Analysis and Prevention*, Vol. 32, 2000, pp. 493–504.

McCartt, A. T., N. R. Schneider, B. E. Wright, and S. Z. Fuller. Driver, Carrier, Vehicle, and Other Variables Related to an Out-of-Service Determination Resulting from a Roadside Truck Safety Inspection. Proc., 2nd International Large Truck and Bus Safety Symposium, 1999.

Moses, L. N., and I. Savage. The Effectiveness of Motor Carrier Safety Audits. *Accident Analysis and Prevention*, Vol. 24, 1992, pp. 479–496.

Murray, D., S. Turrentine, B. Lantz, and S. Keppler. Predicting Truck Crash Involvement: Developing a Commercial Driver Behavior Model and Requisite Enforcement Countermeasures. Presented at 85th Annual Meeting of the Transportation Research Board, Washington, D.C., 2006.

Office of the Inspector General. *Improvements Needed in the Motor Carrier Safety Status Measurement System*. Office of Inspector General, U.S. Department of Transportation, 2004.

Officer of Motor Carrier and Highway Safety. *New Entrant Safety Research: Analysis Brief*. Publication FHWA-MCRT-99-009. Office of Motor Carrier and Highway Safety, U.S. Department of Transportation, 1999.

Patten, M. L., J. L. Carroll, and E. A. Thomchick. The Efficacy of Roadside Inspections in Reducing Heavy Truck Accidents. *Journal of the Transportation Research Forum,* Vol. 29, No. 2, 1989, pp. 269–276.

Shaffer, S., and L. Loy. Implementation of Performance-Based Brake Testers in North America. Proc., 2005 International Truck and Bus Safety and Security Symposium, Alexandria, Va., 2005.

TML Information Services, Inc. *Commercial Driver License Effectiveness Study: Executive Summary*. Cooperative Agreement DTFH61-95-X-00029. TML Information Services, Inc., Forest Hill, N.Y., 1998.

Tanner, S. A., R.W. Tarr, and J. White. A Computer-Based Safety Inspector Training and Certification Program. *Proc., 2005 International Truck and Bus Safety and Security Symposium*, Alexandria, Va., 2005.

Volpe National Transportation Systems Center. *SafeStat Effectiveness Study Update*. Volpe National Transportation Systems Center, Cambridge, Mass., 2004.

Health and Wellness of Commercial Drivers

GERALD P. KRUEGER
MICHAEL H. BELZER
ALBERT ALVAREZ
RONALD R. KNIPLING
E. LEE HUSTING
REBECCA M. BREWSTER
JOHN H. SIEBERT

This chapter reviews important health and wellness topics pertaining to commercial truck, bus and motorcoach drivers, with discussion focused on those factors that directly affect driving safety. Some driver health issues are addressed in less detail here because they are not so obviously connected to driving safety per se. Numerous health and wellness topics to select from include those as far reaching as

- Epidemiological surveillance of diseases, illnesses, job injuries, and resultant OSHA statistics portraying incidences of commercial vehicle driver injuries and death;
- Proper diet, nutrition, limiting alcohol and tobacco use, maintaining proper weight and physical fitness levels, psychological and physical stress, workload, participating in stress alleviation programs;
- Health and safety consequences of shiftwork, irregular and extended work schedules, missed or broken sleep, circadian rhythm disruption, loss of driver alertness, and driver fatigue;
- Sleep maladies, sleep disorders, chronic partial sleep deprivation, resultant drowsiness, and driver fatigue;
- Whether declining driver fitness and health lead to driving safety risks, e.g., a lack of alertness;
- Whether leading a health-conscious lifestyle makes drivers behaviorally more apt to be safe on the roads; and if so, identifying how to foster healthy lifestyles through general wellness education programs;
- Whether wellness programs advocating healthy lifestyles actually make sizeable differences in driving safety now, while the CMV driver is still employed—or only improve a driver's quality of life and possibly extend life expectancy; and
- Medical checkups and health criteria used to qualify CDL holders to drive CMVs—determining certification and training for medical personnel who certify drivers on CDL physical exams.

It is the intent of this chapter to dwell on health and wellness topics that have a clear link to driving safety. For example, although chronic tobacco smoking may affect one's health, it is not so readily apparent that smoking by itself or its accompanying health consequences directly impact driver safety.

At a conference on truck driver occupational health and safety (Saltzman and Belzer, 2003) it was pointed out that in 2001, truck drivers accounted for more than one-eighth of the fatal occupational injuries (799 of 5,900) in the United States, while CMV drivers only accounted for a relatively small percentage of the total of American workers at risk (www.ilir.umich.edu/tibp/truckdriverosh/). In 2001, truck drivers also accounted for one-twelfth of all nonfatal occupational injuries and illnesses involving days away from work (129,068 of 1,537,567) according to the Bureau of Labor Statistics (BLS) Census of Fatal Occupational Injuries (CFOI) in 2001. In 2002, U.S. truck drivers had 112,000 days off work due to illness or injury, while construction workers had one-third the number and carpenters had one-fourth as many days off (BLS, 2002). For occupations with at least 30 fatalities, truck driving was among the 10 occupations with the highest rate of fatal occupational injuries in 1993.

Detailed information on fatal and nonfatal work-related incidents available from the CFOI and the Survey of Occupational Injuries and Illnesses of BLS suggests that even after considering annual fluctuations, highway incidents accounted for nearly one-fourth of fatal work injuries. From 1992 to 2001, highway transportation incidents were the leading cause of workplace death, with more than 13,500 workers killed, an average of three worker deaths per day. Occupants of trucks accounted for nearly 60% of fatalities; almost half of these were semi-truck occupants (Pratt, 2003).

Saltzman and Belzer (2003) also pointed out that there was anecdotal evidence that occupational illnesses diminished the quality of life for many truck drivers, may lead to premature death, and that further research was needed on commercial driver health issues (Saltzman and Belzer, 2002). Participants at that 2003 Occupational Health and Safety Conference identified a number of more directly relevant concerns over health and wellness of CMV drivers:

- Truck drivers tend to develop chronic diseases such as diabetes at relatively early ages; more than 50% of CDL drivers are regular smokers; many CMV drivers are obese; most commercial drivers lack for proper physical exercise; and they may have slightly elevated suicide rates. These points also are documented in studies of trucker wellness issues cited by Roberts and York (2000).
- About half of driver injuries involving lost workdays are attributable to sprains, often caused by overexertion such as lifting heavy objects (from U.S. Department of Labor job injury statistics).
- Sleep loss, sleepiness, and driver fatigue increase the risk of operational errors, unsafe driving, injuries, and deaths.
- Work-related environmental exposures (e.g., to diesel exhaust and other toxic fumes, continuous noise and vibration) may be associated with chronic respiratory diseases, reductions in pulmonary function, allergic inflammation, hearing loss, and other conditions which can have driving safety implications (Saltzman and Belzer, 2003) (http://www.ilir.umich.edu/tibp/truckdriverosh/).

Husting and Biddle (2005) outlined how commercial driving fit the public health model and stated that motor vehicle safety was recognized as an important public health problem that particularly involved commercial drivers. Solomon et al. (2004) pointed out that the workplace of commercial drivers was in fact the community and thus the health of the commercial driver population was of special interest. Several studies suggest an association between illnesses among commercial drivers and the increased likelihood of fatal motor vehicle crashes with other drivers among the general public (Stoohs et al., 1994; Dionne et al., 1995; McCart et al., 2000; Hehakkanen, 2001). This chapter cannot do justice to all the topics above. Eleven health-related matters considered by the authors to have a direct relationship to commercial driving safety are addressed here. In each section, information is linked to federal regulations for commercial drivers, and practical safety management guidance provides for some topics. Where applicable, gaps in current knowledge that call for more research are pointed out.

MEDICAL AND HEALTH ISSUES AFFECTING COMMERCIAL DRIVER SAFETY

Cardiovascular Illness and Heart Disease

Cardiovascular disease (CVD) is a leading cause of illness and sudden death in the general population. Likewise, CVD impacts the health and safety of commercial vehicle drivers (Rafnsson and Gunnarsdottir, 1991; Bigert et al., 2003). The growing number of commercial drivers, coupled with the prevalence of CVD in the United States, makes certain that heart-related illness will have an increasingly powerful impact on the health and safety of CMV drivers (Blumenthal et al., 2002). However, only a few published studies address CVD, myocardial infarction, or ischemic heart disease (IHD) as these affect truck and motor coach drivers. Robinson and Burnett (2005) cite only three U.S. studies on IHD in U.S. truck drivers. Luepker and Smith (1978) examined the mortality of Teamsters Union members and reported no excess risk for heart disease. An ecologic study of cardiovascular disabilities and stress found elevated risk of heart disease in truck drivers (Murphy, 1991), and the California Occupational Mortality Study (COMS) reported significantly elevated standardized mortality ratios for lung cancer and heart disease in California long-haul drivers (COMS, 1987).

Robinson and Burnett (2005) state that lifestyle and occupational factors combine to give truck drivers a unique constellation of risk factors for CVD. Lifestyle factors include poor diet, sedentary jobs, and a higher prevalence of cigarette smoking than found in many other occupations. Worksite factors include long hours, vigorous exertion, strict road rules, stress, fatigue, and potential exposure to high noise levels, diesel fuel combustion exhaust, carbon monoxide, lead, freon, and the vast array of substances carried as cargo (Robinson and Burnett, 2005). Roberts and York (2000) point out that many factors common among truck drivers (elevated blood cholesterol, high blood pressure and hypertension, diabetes, being overweight, lack of aerobic exercise, and smoking) contribute to chronic and acute cardiovascular illness that could lead to myocardial events while driving.

An NTSB study (NTSB, 1990) described crashes fatal to drivers of heavy trucks, and reported 19 of 185 fatally injured truck drivers (10%) in the core sample studied had such severe health problems that NTSB pinpointed health as a major factor in, or the probable cause of, the crashes studied. Seventeen of those 19 crashes (89%) involved a form of cardiac incident at the time of the accident, e.g., sudden incapacitation of the driver due to an acute heart problem. NTSB said that percentage might be a conservative estimate because information in other accident reports indicated possible cardiac problems that were not confirmed because autopsies had not been conducted. In the 15 years since the examination of those accident report data, some major newsworthy truck crashes have involved professional drivers who apparently had heart attacks while driving commercial vehicles.

Published U.S. DOT medical guidelines assist medical examiners in performing the evaluation and certification of each driver. As the agency responsible for setting the medical qualifications for commercial drivers in interstate commerce, the FMCSA sets the medical criteria [Regulation 49 CFR, Part 391.41 (b) (4)] requiring that a CMV driver have no current clinical diagnosis of myocardial infarction, angina pectoris, coronary insufficiency, thrombosis, or any other CVD of a variety known to be accompanied by syncope, dyspnea, collapse, or congestive cardiac failure.

FMCSA obtains active participation and consultation from cardiac specialists frequently to review and update the medical guidelines to ensure that they reflect the latest in cardiovascular health trends and medical advances in diagnosis and therapy. In 2001, FMCSA convened a medical advisory panel to develop new revised cardiovascular guidelines for the medical examination of CMV drivers (Blumenthal et al., 2002). These latest guidelines highlight the numerous advances made in medical diagnosis and management of CVD and help ensure that a larger number of commercial drivers will be able to continue to work even though they have been diagnosed with CVD, but are being properly treated for it.

The guidelines are significant, because for the first time the level of risk of sudden incapacitation has been set and quantified (available from FMCSA) for the risk of myocardial infarction from coronary heart disease. Below this level, an asymptomatic driver is identified as safe, and above it, the driver must prove that he or she is safe by participating in an exercise tolerance stress test (ETT) through six multiples of the resting metabolic rate (METS).[1] Since the number of drivers working past age 65 years old is likely to continue to increase, many more older drivers will be getting stress tested.

Medical examiners make judgments on an individual basis of whether the nature and severity of a driver’s condition will likely cause sudden incapacitation. Medical practitioners in clinics doing commercial driver physical exams benefit from having driver cardiovascular risk information and medical lab test results [e.g., total cholesterol and high-density lipoprotein (HDL)] on which to make risk assessments, but such helpful information is not always readily available without ordering additional medical tests, e.g., a treadmill test. As newer cardiovascular guidelines are issued, occupational medicine physicians who conduct CDL physicals are more likely to require such additional medical testing to meet the CDL medical certification process involving cardiovascular issues. Research to make this process more effective is warranted.

Diabetes

Diabetes mellitus (sometimes called sugar diabetes) is a disease in which the body does not produce sufficient insulin or does not properly utilize the insulin produced. Insulin is a hormone essential to metabolize glucose properly to maintain the proper blood sugar level in the body. A person with diabetes fails to metabolize glucose in the normal way; this leads to metabolic changes that can have adverse effects on the body, including changes in the blood vessels and nerves that make them more susceptible to damage. Diabetics have increased occurrence of eye disorders, kidney disease, arteriosclerosis, and heart disease. Poor circulation in the feet and legs attributable to diabetes may lead to problems with the peripheral nerves and vasculature of the extremities. These commonly develop into foot problems; sometimes accompanied by gangrene and eventually even necessitating amputations of lower extremities. Diabetes effects on peripheral nerves often cause numbness or pain in the feet; this has a high potential to affect driver safety (U.S. DOT Neurology Medical Guidelines).

Diabetes may affect a person’s ability to drive, usually because of a hypoglycemic episode, either through loss of consciousness or disorientation in time and space or from end organ effects on relevant functions, including effects on vision, the heart, and particularly the feet. The main safety concern for insulin-dependent drivers is the possibility for unexpected occurrence of hypoglycemic reactions that can cause drowsiness, impairment of perception or motor skills, abnormal behavior, impaired judgment (which may develop rapidly and could result in loss of control of a vehicle) semiconsciousness or unconsciousness (diabetic coma), or insulin shock.

Laberge-Nadeau et al. (1996) found CDL permit holders for single-unit trucks who were diabetic, without complications and not using insulin, had an increased crash risk of 1.68 (i.e., 68% increased risk) when compared with healthy CDL holders of the same permit class. Commercial drivers with a single-unit truck permit and the same diabetic condition had an increased risk of 1.76.

Many CMV drivers work irregular work schedules, rotate work shifts, and often work through the night. Commercial drivers frequently experience circadian desynchronosis, a form of work shift lag (Comperatore and Krueger, 1990) whereby their normal circadian physiological functioning also shifts, sometimes affecting other biological functions. Irregular work hours and resultant chronobiological considerations are important for diabetics and especially critical for shiftworkers. Basal insulin secretion and glucose tolerance normally follow a circadian rhythm.

The blood glucose level normally follows a shorter (ultradian) rhythm of 6 to 8 h (Reinberg, 1989). Plasma insulin response to intravenous antidiabetic drugs (e.g., Tolbutamide, now offered in pill form) to control high blood sugar levels, has been shown to peak early in the morning (around 4 a.m.), but the resulting fall in blood sugar does not follow a circadian rhythm (Sensi, 1976). DelPonte (1979) found the fall of blood glucose in nonobese, mild diabetics was higher in the morning in response to insulin, even though in these diabetic patients morning glucose values were higher than afternoon ones, suggesting that mild impairment of carbohydrate metabolism alters the circadian rhythm of basal blood glucose values and glucose tolerance. Lack of sleep, fatigue, poor diet, emotional conditions, stress, and concomitant illness compound the problem by affecting the self-regulatory hormones that keep the blood glucose levels within normal limits.

Commercial drivers who are diabetic need competent medical treatment and prescribed protocols for use of their medications. Diabetic drivers (whether CMV drivers or not) must follow precautionary steps to avoid hypoglycemic episodes. Diabetic drivers must comply with specified periodic diabetes reviews by medical specialists; eat regularly timed carbohydrate-balanced meals to keep their glucose levels within normal or desired limits; monitor their own blood glucose levels; carry supplemental glucose with them in their vehicles; and, should a hypoglycemic episode occur, immediately stop driving. For decades, the self-administration of insulin required insulin, syringe, needle, alcohol sponge, and a sterile technique. More recent innovations include being able to inject insulin right through the clothing into the abdomen.

Medical advisory criteria for evaluation of CMV drivers [see 49 CFR, Part 391.41 (b) (3)] state that a person is physically qualified to drive a CMV if that person has no established medical history or clinical diagnosis of diabetes mellitus currently requiring insulin for control. Individuals who require insulin for their diabetes have conditions that can get out of control by the use of too much or too little insulin or their food intake is not consistent with the insulin dosage. Incapacitation may occur from symptoms of hyperglycemic or hypoglycemic reactions (drowsiness, semiconsciousness, diabetic coma, or insulin shock).

FMCSA has consistently held that a diabetic who uses insulin for control does not meet minimum physical requirements, making insulin-dependent diabetes, normally, a disqualifying medical condition for commercial drivers under FMCSR. See also the conference report on diabetic disorders and commercial drivers (Whitehouse, 1988).

Commercial drivers with diabetes may begin with Type II diabetes (non-insulin dependent) but often progress, through weight gain, inactivity, and inability to control dietary factors to blood sugar levels where insulin would be required and cause them to lose their medical certification. For these reasons, drivers' blood sugar control can become suboptimal, putting them at increased risk for complications due to the diabetes as mentioned above. The point at which a commercial driver requires further control of his/her diabetes, up to and including supplementary insulin, has been defined by the American Diabetes Association as a postprandial meal (lunch) glucose of 235 mg/dl or more appropriately a Hemoglobin A_1C of 10.

FMCSA examined the research results on the effects of insulin-treated diabetes on driver performance; then did a review of U.S. DOT, FAA, and state exemption programs; and obtained substantial medical input from a panel of endocrinologists. FMCSA determined that in some cases diabetes and its adverse effects can be successfully controlled and monitored in the CMV driver population. FMCSA established a program to exempt certain insulin-treated diabetic truck and bus drivers from FMCSRs (FMCSA, 2001). FMCSA's CMV driver diabetes exemption program has three components: (*a*) screening to identify qualified applicants; (*b*) provision of guidelines for managing diabetes while operating a CMV, including supplies to be used and the protocol for monitoring and maintaining appropriate blood glucose levels; and, (*c*) a specific process for monitoring insulin-treated commercial drivers, including specifying the required medical examinations and the schedule for their submission. The diabetes exemption program indicates how glucose measures should be taken and reviewed and how episodes of severe hypoglycemia and incidents should be reported. Health and wellness programs promoting tight control of diabetes reduce diabetic complications for drivers. The diabetes exemption period for commercial drivers is for 1 year but FMCSA may renew individual driver exemptions near the expiration of the exemption period.

Epilepsy

Epilepsy is a disorder of cerebral function, an electrical abnormality in the brain, which can be present at birth or occur later in life. Epilepsy is a tendency to have seizures or, more technically, a tendency to recurrent episodes of alteration of consciousness or control, associated with indications of abnormal overactivity of at least some part of the brain, at the time of an epileptic attack. If the overactivity remains in one area of the brain, the result is a localized or special kind of seizure. If it spreads throughout the brain, a more generalized seizure may result. After the attack is over, the brain cells return to their normal state. Thus, except for the brief time of a seizure, the person with epilepsy is usually able to function normally.

The cumulative incidence of epilepsy is about 2% to 3% of the general population, with about 0.5% affected and taking antiepileptic medication at any one time. With the appropriate drug treatment, seizures can be completely controlled in up to 80% of epileptics. Most epileptics respond well to treatment, and the majority of epileptics suffer few seizures in a lifetime.

Epileptic seizures occur without warning and vary considerably. Some are purely subjective experiences, such as a simple partial seizure, but the majority of seizures involve loss of voluntary control and some impairment of consciousness. An isolated seizure is not necessarily synonymous with epilepsy. So-called safe-seizures—light, brief, episodic disturbances not involving convulsive form—occur only at a particular time of day, such as shortly after awakening. Petit mal epilepsy consists of sudden losses of consciousness lasting only a few seconds. Other less common kinds of seizures simply involve slight muscle jerking. These less-threatening seizures must be acknowledged, and a response to them must be developed.

Epileptics are at increased risk of ill effects from unusual work hours. In a review of the literature, Tharp (1982) observed that lack of sleep leads to an increased frequency of seizures in some epileptics. Sleep deprivation of 24 to 36 h can cause electroencephalograph (EEG) activation in epileptics. In many patients in whom this has been observed the usual seizures are related to sleep loss (Pratt, et al., 1968). Beregonzi, Chuunvilla and Tempesta (1973) found that rapid eye movement (REM) stage sleep (dreaming) deprivation activates EEG epileptic activity and sometimes clinical seizures in persons with generalized or focal epilepsy.

Responsible individuals with well-managed epilepsy (as demonstrated by an appropriate seizure-free period of time) may be considered fit to drive. Individual responsibility on the epileptic's behalf means personal accountability for management of his or her condition with the support of a medical practitioner. The linkage between sleep deprivation and epileptic activity makes it critically important that all drivers who might have even a mild case of epilepsy obtain adequate sleep and not drive when sleep deprived and that they be monitored frequently.

An isolated seizure while driving, when accompanied by a brief loss of awareness or loss of motor control, can impair a driver's ability to control a motor vehicle and present a considerable safety risk. Vehicle drivers who experience an isolated seizure must cease driving immediately until proper medical diagnosis and a proper determination regarding continued driving status can be made. In the event of recurrent seizure, medical treatment and evaluation are indicated.

FMCSA declares a person unqualified to drive a CMV if that person has an established medical history or clinical diagnosis of epilepsy or any other condition that is likely to cause the loss of consciousness, or any loss of ability to control a CMV [49 CFR, Part 391.41 (b) (8)]. Further, that medical advisory states that epilepsy is a chronic functional disease characterized by seizures or episodes that occur without warning, resulting in loss of voluntary control which may lead to loss of consciousness or seizures. Therefore the following drivers cannot be qualified to drive CMV on U.S. highways:

- A driver who has a medical history of epilepsy,
- A driver who has a current clinical diagnosis of epilepsy, or
- Adriver who is taking antiseizure medication.

Obesity

During the past decade, there has been a tendency for medical specialists periodically to adjust the definition of what constitutes being overweight or being obese. In general, it means not maintaining suitable body fat levels. A person's fat content is evaluated in terms of the percentage of body mass that is fat. Obesity is an excessive amount of body fat, or the excess storage of energy in adipose tissue. Generally, the obesity range is a body weight greater than 5% more than one's ideal body weight (average) for one's height and gender (McArdle et al., 1991; Harig et al., 1995).

For young men aged 17 to 27, ideal average body fat measures would be about 15% of body mass, and therefore the borderline measurement for obesity would be 20% body fat (i.e., a

200-lb man with 40 lb of fat would be considered obese). For men aged 27 to 50, whose average fitness measure is approximately 25% body fat, obesity would be defined as a body fat content that exceeds 30%. Between men and women there are obvious differences in body makeup, biomechanical structure, and weight distribution. Categorization of obesity for women is also different. Thus, for young women aged 17 to 27, obesity would correspond to a body fat content above 30%. For women aged 27 to 50, the borderline between average and obesity would be greater than 37% body fat (McArdle et al., 1991; Harig et al., 1995). Many technical references to obesity describe body measures in terms of body mass index (BMI). This accepted practical definition of obesity for clinical use is expressed in weight per unit of height (kg/m^2).

Medical personnel can readily identify health-related concerns for obesity in commercial drivers. They include a well-established risk factor for CVD, hypertension, diabetes, or stroke (Roberts and York, 2000) and for obstructive sleep apnea (Pack, Dinges, and Maislin, 2002). Obesity, or even being slightly overweight, can exacerbate conditions of arthritis, back pain, especially low back pain (Miyamoto et al., 2000), and other musculoskeletal disorders such as carpel tunnel syndrome. Obesity also presents higher risk of cancer when it accompanies other health-related conditions such as low activity levels, diabetes, or even having recently gone through menopause. The American Medical Association published *Assessment and Management of Adult Obesity: A Primer for Physicians* (Kushner, 2003) in an attempt to encourage physicians to accentuate health promotion and disease reduction issues involving obesity.

Research literature specifically relating obesity to driver safety and performance is scant and difficult to locate. Inability to maintain healthy body weight levels and body fat levels, however, has at least an indirect bearing on a driver's ability to maintain safe driving posture and practices continuously. Stoohs et al. (1994; 1995) reported a direct relationship between BMI and driver crash likelihood in a dose-dependent fashion.

During an ergonomics assessment of Class 8 truck safety belts, Krueger found that numerous obese, "large-bellied" commercial truck drivers do not wear their safety belts (Bergoffen et al., 2005). Large drivers contend that shoulder belts, mounted on the truck cab B-post do not "hang properly" over the driver's shoulder and on the large chest of big drivers, and when secured, the lap belts tend to cut into the belly. Many large drivers simply do not use their truck safety belts because they find the belts uncomfortable. This can contribute to a more serious crash outcome for these drivers.

Obesity in commercial drivers might practically affect driving safety in other ways:

- Ability or inability to climb into and out of the cab of a truck or to climb around and secure cargo loads in or on a truck and trailer [exemplified by numerous slip, trip, and fall incidents in the U.S. Department of Labor and National Institute for Occupational Safety and Health (NIOSH) workplace injury and worker compensation data bases];
- Distractions due to discomfort while seated for extended periods in the truck and therefore an inability to give continuous full concentration and attention to driving tasks (e.g., squirming in the seat in attempts to get comfortable, experiencing back pain, etc.);
- Inability to perform truck cargo loading and unloading chores to satisfaction (Krueger and VanHemel, 2000); and
- Interactions of being substantially overweight with a driver's ability to maintain overall high physical fitness and the likelihood that obesity contributes to driver fatigue, because additionally, obesity often accompanies obstructive sleep apnea (covered under sleep disorders later in this chapter).

Vision Considerations

Safe and proper operation of motor vehicles requires excellent vision in terms of visual acuity, breath of visual field, and color vision.

Good visual acuity is required for many driving tasks. A significant loss of visual acuity, or loss of visual fields, diminishes a person's ability to drive safely. However, the level of vision necessary for safe driving has been a contentious issue because of the unavailability of definitive empirical evidence on which to base a clearly defensible visual performance standard (Decina and Breton, 1993). It is generally accepted that a driver with uncorrected visual defects (i.e., without prescription lenses) may fail to detect other vehicles, pedestrians, or roadside barriers and may take appreciably longer to read road signs at a distance or at night or to perceive and react to hazardous situations. Fortunately, prescription lenses can compensate for most forms of degraded visual acuity to permit most drivers to have adequate acuity for driving. Since the federal government began regulating vision standards for motor carriers in interstate commerce during the late 1930s, the purpose of setting vision standards for drivers of CMVs has been to identify individuals who represent an unreasonable and avoidable safety risk if allowed to drive CMVs. Federal regulations, specifically those covered by 49 CFR 391.41 (b) (10), require a driver to have distant visual acuity of at least 20/40 (measured via Snellen eye chart test) in each eye with or without corrective lenses, or visual acuity separately corrected to 20/40 (Snellen) or better with corrective lenses, and distant binocular acuity of at least 20/40 (Snellen) in both eyes with or without corrective lenses.

Recently, laser surgery techniques proliferated for enacting vision corrections, but laser surgery can be associated with several effects that bear on driver safety, including that of commercial drivers who have recently had laser surgery. According to the U.S. Food and Drug Administration (FDA) Center for Devices and Radiological Health (2006) some patients who have had laser surgery have instability of visual acuity, which may decline during the waking hours. After undergoing this procedure, some drivers may have different visual acuity at different times of the day, worsening by as much as two lines of the Snellen chart (which could result in visual acuity not meeting medical guidelines). Additionally, some people who undergo the vision-correcting eye surgery procedure known as Lasik (laser-assisted in situ keratomileusis) may experience glare, halos, and starbursts around lights at night, which could be troublesome while driving. The effects may take a few months to disappear. The vision medical guideline does not address these issues. It is not known how many commercial drivers undergo increasingly popular laser surgery for vision corrections. More research is needed on this set of visual issues relating to laser surgery outcomes.

An aging driver population experiences vision changes associated with age, most particularly cataracts. Cataracts are opacities of the lens attributable to a biochemical change in structure in the eye. People with cataracts experience more glare, particularly at night when the headlights of oncoming traffic reflect off the cataract before hitting the retina. This results in loss of visual acuity and could result in difficulty perceiving the driving environment. Testing for this condition is available but not required in the commercial driver examination (U.S. DOT vision medical standard). More research on the effect of cataracts and driving performance is warranted.

An adequate visual field is important for driving, and peripheral vision is particularly important in tasks such as changing lanes, merging into a traffic stream, and detecting pedestrians about to cross into traffic. Severely restricted visual fields impair driving performance and can increase crash risk (Johnson and Keltner, 1983; Wood and Troutbeck, 1992; 1994; Coeckelberg et al., 2004). U.S. DOT standards, [49 CFR 391.41 (b) (10)] require commercial drivers to have fields of vision of at least 70 degrees in the horizontal meridian in each eye. Decina and Breton (1993) suggest that this aspect of the standards should be revisited because the field-of-view of a normal healthy adult is closer to 140 degrees for each eye.

Visual field losses can result from eye diseases such as retinitis pigmentosa (inherited degeneration of the retina causing significant visual field loss by age 30) or conditions such as glaucoma, optic atrophy, retinal detachment, or localized retinal or choroidal infection. Visual fields can also be reduced by head trauma, brain tumor, stroke, or cerebral infection. Good rotation of the head and neck also is necessary to ensure an adequate field of vision.

Drivers generally need good color vision for some driving tasks. Federal regulation CFR 49 391.41 (b) (10) requires a driver to recognize the colors of traffic signals and devices showing standard red, green, and amber. A driver with red-deficient vision would have some difficultly detecting and relating to red traffic lights at road intersections and in seeing rear braking lights on other vehicles. In effect he/she would have to rely upon seeing the brightness of the lights rather than the red color per se. However, there is no solid evidence that color-blind drivers are less safe drivers. Recent improvements in traffic sign engineering to modify the hue and intensity of traffic lights help persons with red deficiency. Decina and Breton (1993) point out that the color requirement does not exclude red–green color-defective drivers since the standard does not provide adequate instruction on requirements for color vision testing. They also state that it is doubtful that the standard intended to exclude typical red–green color-defective drivers since these drivers are currently on the road and there is a lack of evidence that their safety record is worse than the records of those without such color vision defects. One of the problems with the standard is the lack of an adequate description of the specificity of testing stimuli, lighting conditions, equipment, or uniformity of testing procedures (Decina and Breton, 1993). This area might warrant some additional research.

Dark adaptation is important for night driving. “Night-blind drivers” do not adapt to darkness well, can become involved in night-driving crashes, and may need to be restricted to daytime driving activities. Driver testing does not check for night blindness conditions.

Persons with progressive eye conditions such as cataracts, glaucoma, diabetic retinopathy, optic neuropathy, and retinitis pigmentosa require counseling by appropriate medical authorities and periodic checkups to determine if their eye conditions have worsened and progressed to the stage where for safety reasons they should no longer drive (Coeckelbergh et al., 2004). Commercial drivers with such conditions may require encouragement to select another form of employment. Their vision should be monitored regularly, and when their loss of acuity or loss of visual fields is such that they are no longer safe to drive, they should surrender their CDLs and other driving licenses as well.

If visual criteria are used to determine fitness to drive, sensitivity and specificity of the vision tests should be high. However, as Coeckelbergh et al. (2004) point out, numerous studies cited in the scientific literature suggest that although the relationships between vision requirements and driving safety are significant, they are not conclusive with regard to the identification of individual at-risk drivers (Ball et al., 1993).

For more information, see the section on visual disorders and commercial drivers at www.fmcsa.dot.gov/rulesregs/medreports.htm. In the regulatory agenda published June 28, 2004, FMCSA issued a notice of proposed rule making to develop a new vision requirement based on a panel of vision experts from Harvard University.

Areas for conducting additional driver vision research include

- Continued evaluation of vision requirements for older drivers,
- Evaluation of changes in driver visual capabilities after they have undergone the latest forms of corrective eye surgery (e.g., laser surgery to correct distance visual acuity),
- Determination of what constitutes acceptable vision waivers for CDL drivers, and
- Additional human engineering evaluations of alternative technologies and new formats of presenting roadway signing, especially those signs intended to be read at a distance during night driving, and roadway signs that must be read by a wide variety of drivers who may not have perfect or corrected vision.

Hearing Requirements

Responsiveness to critical events is an important safety consideration for drivers of CMVs. CMV drivers require a reasonable level of hearing to ensure their awareness of changes in engine or road noises that may signal developing problems. They also need their hearing awareness to respond to horns, railroad crossings, and the signals and sirens of emergency vehicles.

Most people with a significant hearing loss are aware of their disability. However, because hearing loss is gradual and insidious, people with a mild hearing loss often are not aware of it. A driver with a mild hearing loss often is able to compensate for his/her impaired hearing, even without wearing a hearing aid, by being more cautious and relying more on visual cues. A moderate to substantial hearing loss does not appear to affect adversely a driver's ability to drive safely when that driver compensates for his/her hearing loss by wearing professionally fitted hearing aids.

There is no medical requirement for commercial drivers to be able to communicate well through spoken word. The hearing level expected of commercial drivers during their medical examinations is such that drivers with profound hearing loss may be permitted to drive CMVs. The hearing requirement is only to "hear a forced whisper at greater than or equal to 5 feet" or have an "average hearing loss of no more than 40 decibels." Communication requirements of a specific job may preclude such a driver from working for a particular employer, but medical criteria do not preclude certification for a CDL.

FMCSA currently requires that all persons seeking a CDL possess a certain minimal level of hearing. Hearing criteria in 49 CFR 391.41 (b) (11) state that a CMV driver cannot have an average hearing loss in the better ear greater than 40 dB(A) at 500Hz, 1,000 Hz, and 2,000 Hz with or without a hearing aid or be able to perceive a forced whisper from no less than 5 ft away.

In an attempt to control noise exposure and interference with hearing while driving, FMCSA Regulation 49 CFR 393.94 states that the interior sound level at the driver's seating position of a motor vehicle must not exceed 90 dB(A) and provides a test procedure. This regulation was published in 1973 and was amended in 1975 and again in 1976.

Hearing can be tested with either a pure-tone hearing test or a forced-whisper (live voice) test. After extensive literature review on topics related to hearing and driving, Robinson, Casali, and Lee (1997) used a human factors engineering approach to estimate the appropriate hearing levels required in driving CMVs, and to evaluate the methods specified to test drivers' hearing. Task analyses, hearing tests, noise measurements, and analytical methods were used in performing the evaluation for FMCSA. Results indicated that some truck-driving tasks require the continual use of good hearing, that truck drivers could potentially suffer hearing loss from noise exposure and that truck cab noise in the 1990s model trucks studied compromised the intelligibility of live and citizens band (CB) radio speech, as well as the audibility of internal and external warning signals. Robinson, Casali, and Lee (1997) recommended several truck cab and warning signal design changes.

In a field study to relate driver exposure to continuous acoustical noise to hearing loss, Seshagiri (1998) assessed the noise exposure in truck cabs by taking more than 400 measurements to determine the ambient noise levels to which truck operators are exposed while taking lengthy drives. Seshagiri took noise measurements at the driver's head position in a variety of trucks (in long-haul, pickup and delivery, and sleeper berth truck samples) while drivers operated in driving conditions:

1. With all truck cab windows and vents closed, radio and CB not operating;
2. All windows and vents closed, radio operating, CB may or may not be operating;
3. Driver's side window open, radio and CB not operating; and
4. Driver's side window open, radio operation, CB may or may not be operating.

Driving with windows closed and the radio not operating resulted in the lowest exposure, ranging from 78 to 89 dB(A), with a mean of 82.7 dB(A). Operating the radio increased the mean by 2.8 dB(A), driving with the driver's side window open increased the mean exposure by 1.3 dB(A), and driving with the window open and operating the radio resulted in an increase of 3.9 dB(A). Trucks with cabs mounted over the engine appeared to be quieter than standard trucks by about 2.6 dB(A). Operations on four-lane highways were 1.6 dB(A) noisier than on two-lane highways, seemingly attributable to the higher speeds driven. Line-haul operations on hilly terrain were quieter than on flat terrain by about 2.2 dB(A), again indicating the effect of driving at higher speed.

Seshagiri found some personal driver samples for which driving with the windows closed and the radio on resulted in measures as high as 85.5 dB(A); driving with the window open and the radio on resulted in 86.6 dB(A) levels. Ten percent of the long-haul drivers in Seshagiri's tests exceeded 90 dB(A) while 53% had an average noise level that exceeded 85 dB(A). Seshagiri's measurements indicate that some truck drivers, at least some of the time, incur a significant risk to their hearing depending on the operating conditions, in particular when they routinely drive with the driver's side window open, and use their radio at a relatively high volume. The risk of hearing loss among drivers of repeated extra-long duration trips is of concern (Seshagiri, 1998).

Many of the older trucks are still in use on our highways long after the Robinson, Casali, and Lee (1997) and the Seshagiri (1998) data were collected; but many newer truck cabs on the road today have been designed to be quieter. The recommendations of the Robinson, Casali, and Lee report may need updating in another road measurement truck cab noise study. Since OSHA now promulgates workplace noise exposure limits approximating 85 dB(A) at the operator's head position, perhaps the 49 CFR 393.94 should be reevaluated for sustained periods of truck driving. Areas for future research then include collecting additional measurements of ambient noise in current truck models; the need to develop an audiometric database for truck drivers; and to continue assessment of the validity and in-practice application of the forced-whisper test.

Effects and Interactions of Prescribed and Nonprescribed Drugs

FMCSA's report to Congress on the LTCCS is an in-depth assessment of a nationally representative sample of large-truck fatal and injury crashes during 2001 to 2003 (FMCSA, 2006). The report stated that among truck drivers, prescription drug use was an "associated factor" in 28.7% of all crashes sampled, and over-the-counter drugs were an associated factor 19.4% of the time. FMCSA indicated an associated factor may not have contributed to a crash, but what was known is that the factors were present at the time of the crashes.

Drivers sometimes take prescription or nonprescription medications and other chemical substances and drugs (e.g., dietary pills, antihistamines): (*a*) as treatment for illnesses or for relief from symptomatic ailments, (*b*) as self-administered countermeasures to fatigue (e.g., stimulants or hypnotics), or (*c*) for recreational purposes (e.g., alcohol, psychotropic substances). Some medications, or drugs, not only bring the driver relief from the discomfort and symptoms of various illnesses, or ailments, but such chemical substances also can have an impact on maintenance levels of driver alertness, and therefore can affect driving performance and safety.

Prescribed medications taken under a physician's orders may treat some medical condition or ailment (e.g., drugs prescribed for hypertension, cholesterol control, heart conditions, depression, and other illnesses and conditions). Drivers may take a variety of prescription or over-the-counter nonprescription medications (e.g., sedating or nonsedating antihistamines, pain relievers) for treatment or relief from respiratory ailments such as asthma, chronic bronchitis, emphysema, seasonal allergies (e.g., hay fever, rhinitis). Some drivers self-administer dietary supplements (weight-loss or appetite-suppressant pills), performance and mood enhancers, energy-boosting drinks, pills, food bars, stimulants (including caffeine from various sources), hypnotics (sleeping pills, melatonin), alcohol, and other chemical substances.

There is not enough scientific evidence on the performance effects of many such medications, either when administered singly or in combination with other chemical substances. The interactive and synergistic effects of many medications, drugs, and other chemicals that drivers ingest are largely unknown. Some medications and chemical substances have side-effect caution warnings on printed instructions inside drug packaging or on the side of containers. Other side effects for commercially available drugs are published in the Physicians' Desk Reference. However, the performance effects of many of the substances drivers ingest are not so easily known. Results from pharmaceutical company proprietary research on such topics are not readily available.

There is a considerable body of research literature available on the performance effects of various stimulants or alertness-enhancing compounds (Babkoff and Krueger, 1992; Vanderveen et al., 2001; Caldwell and Caldwell, 2003, 2005). In a less-than-systematic way, this information is slowly becoming available to the commercial driving industry. For a variety of reasons there is a common belief that most stimulants (e.g., amphetamines) may lead to drug addiction and abuse and that driving performance under the influence of stimulants would not be consistently and reliably predictable. Therefore, most stimulants (a notable exception is caffeine) are forbidden worldwide in the commercial driving community. At present, the commercial driving industry appears to have considerable control over drug use in the employed work force. This it has done through enforcing randomized urine sample testing of drivers for recreational and drugs of abuse and imposing harsh penalties such as loss of one's job for positive test results, albeit some commercial drivers are still testing positive for such illicit drug use. Thus far, the only consensus agreement for allowable use of a stimulant by commercial drivers is that for consumption of caffeine (Vanderveen et al., 2001; LaJambe et al., 2005). Caffeine certainly is readily available in numerous formulations and delivery mechanisms, including coffee, tea, soft drinks, contained in certain bottled water products, included in chocolate candy, available in pill form, and soon will be available in alertness-promoting chewing gum (Kamimori et al., 2002), which is already issued by the supply system in the U.S. Army.

Recent military medical research lab results suggest that Modafinal (available in the United States by prescription as ProVigil®), a mild stimulating compound without the many drawbacks of traditional stimulants, offers promise in select military applications (McLellan et al., 2002; Wesensten et al., 2004). In more recent research, Modafinal reduced the extreme sleepiness observed in patients with shift-work sleep disorder and resulted in a small but significant improvement in performance as compared with placebo (Czeisler et al., 2005). However, the residual sleepiness observed in the Modafinil treated patients, especially at night, underscored the need for development of interventions that are even more effective if one day in the future either Modafinal, or its successors, might demonstrate acceptability for safe driving in some trucking or motorcoach applications as well.

As for hypnotics (i.e., sleeping pills or sleep-promoting compounds), most sleeping pills must be used under a physician's prescription and direction. For circumstances where it is difficult to obtain sleep in operational contexts, the U.S. Air Force and the U.S. Army have approved the limited use of Temazepam, Zolpidem, and Zaleplon. The army also continues to authorize limited use of Triazolam (Halcion) for predeployment rest or sustained operations; whereas Triazolam's association with adverse effects, particularly on memory, has curtailed its use in many clinical settings. These hypnotics can optimize the quality of crew rest in circumstances where sleep is possible but difficult to obtain. Ordinarily, administration of sleeping compounds in military operations is strictly controlled under the guidance of a prescribing physician and the watchful eye of safety officers. The choice of which compound is best for each circumstance must take several factors into account, including time of day, half-life of the compound, length of the sleep period, and the probability of an earlier-than-expected awakening, which may risk more sleep inertia effects. As with most chemical substances, there is a risk of some bodily adaptation to repeated use of hypnotics. There also is some concern for fatigue rebound upon discontinuance of use (one feels more tired than if the drug had not been used in the first place) and often there is a sleep inertia drowsiness hangover effect after awakening from a drug induced nap. For summaries of research studies, and details on these hypnotics and on the afore-mentioned stimulants, see the review by Caldwell and Caldwell (2005).

Recently, there has been much study of the body's natural sleep aid, the hormone melatonin from the pineal gland, as a helpful sleep aid. Melatonin is now available synthetically in pill or tablet form in health food stores. In interviews, many truck drivers admit to using synthetic melatonin, but with mixed reports of success (G. P. Krueger, 2006, personal communication, fatigue and wellness courses). However, since melatonin is declared by the FDA to be a food supplement and not a drug, its manufacture is not governed by FDA-required good manufacturing practices; therefore when purchasing it in a health food store, one cannot be precisely sure of the contents of the tablets in the container. Additionally, the pill form synthetic melatonin is not yet in timed-release capsule form, whereas pineal gland-prompted melatonin is released gradually into our blood stream during the hours of darkness, and ceases upon arrival of daybreak. A considerable amount of ongoing medical research is presently examining applications of melatonin for use as a sleep sedative. With promising results, it appears that soon suitable usage protocols may be determined for inducing sleep through careful use of melatonin (e.g., Reiter and Robinson, 1995; Sharkey, et al., 2001; Paul et al., 2004).

The newer nonsedating antihistamines (second-generation antihistamines that allegedly do not cross the blood–brain barrier) have not yet been proved with documented scientific research to live up to their advertised billing as working to alleviate allergic reactions without imposing drowsiness on drivers. In a comprehensive review, Moskowitz and Wilkinson (2004) point out that there is considerable variation in objective evidence of impairment and in subjective effects such as sedation. Moskowitz and Wilkinson state that some antihistamine drugs will more likely avoid side effects such as sedation and driving-related performance impairment, and they conclude that more scientific information is needed on performance effects related to antihistamines using the most methodologically sound research techniques to permit better comparison between the different new antihistamines under development by the pharmaceutical industry.

For diagnosed conditions of depression (see the section on mental health), physicians prescribe antidepressants to drivers, whether they be automobile or CMV drivers. Ramakers (2003) conducted a review of the major results from all the published studies from 1983 to 2000 on the effects of antidepressants on actual driving performance using a standardized test measuring impairment from vehicular weaving. Ramaekers reported that after acute doses of sedating antidepressants (i.e., amitriptyline, imipramine, doxepin, and mianserin), changes in lateral driving position during 1 h of on-the-road driving in normal traffic were comparable to those seen in drivers conducting the same test with a BAC of 0.8 mg/mL or more. Driving performance of subjects returned to placebo levels after 1 week of treatment, except after treatment with mianserin, for which the impairing effects lasted unabated over treatment. Nocturnal doses of sedating antidepressants (i.e., dothiepin, mianserin, and mirtazapine) however, did not produce residual driving impairment when measured the next day. Non-sedating antidepressants (i.e., moclobemide, fluoxetine, paroxetine, venlafaxine, and nefazodone) generally did not affect vehicular lateral control. Ramakers (2003) concluded that application of actual driving tests remains essential to conclusively defining the potential hazard of drugs for driving.

Significant and relevant research also is unavailable on the interactions (or synergistic reactions) of the numerous chemical substances we humans ingest, as these may adversely affect our performance while driving. What, for example, are the interactive effects on alertness and performance of simultaneous ingestion of some form of prescribed medication (e.g., antihypertension drugs) along with self-prescribed antihistamines for seasonal allergies, all while diet pills, stimulants like caffeine, and or other chemical substancesare being consumed? More medical research is needed to inform the CMV community of the synergistic effects of multiple chemical substances, and to develop acceptable protocols for CMV driving while under their influences.

Not much is known about the extent to which physicians prescribe sleeping pills, antihistamines, dietary measures, and other chemical compounds to commercial drivers. Nor is it known to what extent commercial drivers self-administer readily available over-the-counter medications, chemical compounds, etc., without prescription. This issue, therefore, might be an area of inquiry for future research.

FMCSR 49 CFR 391.41 (b) (12) requires that a driver does not use a controlled substance identified in 21 CFR 1308.11, Schedule I, an amphetamine, a narcotic, or any other habit-forming drug. The rules make an exception for drivers if a substance or drug is prescribed by a licensed medical practitioner who is familiar with the driver's medical history and assigned duties and who has advised the driver that the prescribed substance or drug will not adversely affect the driver's ability to operate a CMV safely.

FMCSR 49 CFR 391.41 (b) (13) permits a person to drive if that person has no current clinical diagnosis of alcoholism.[2]

Stress: Physical and Psychological

Commercial drivers experience many pressures of modern living, including personal financial situations, family concerns, and personal circumstances that many other workers encounter. However, commercial drivers experience their own unique sets of physical and psychological job-related stresses that can directly affect their health, their job performance, and ultimately their road safety. The range of job-related stresses includes physical and mental workloads such as loading or unloading freight on their trucks or waiting for hours in queues for their trucks to be loaded or unloaded (Krueger and Van Hemel, 2001); pressures to make schedules or deliveries on time; staying within the HOS rules; driving in traffic, bad weather, harsh driving conditions, or road construction; and dealing with unruly passengers on motor coaches or with automobile drivers around them.

Psychological stressors cause the body to release hormones such as catecholamines, cortosol, and adrenaline, and this causes heart rate, blood pressure, muscle tension, and blood sugar to rise sharply. The influence of mind over body determines how people respond physiologically to the release of hormones. People respond to and deal differently with psychological stressors. Physiological changes to emotional distress can make people susceptible to health problems. Shift work; irregular, rapidly rotating work-shift schedules; and resultant stress-related sleeplessness lead to fatigue (Scott, 1990, 2000; Rosa and Colligan, 1997; Caruso et al., 2004). Tension headaches and poor concentration can lead to impaired driving and increase the risk of crashes. Ulcers or other gastrointestinal problems from stress cause pain, discomfort, and disrupt concentration (Caruso, Lusk, and Gillespie, 2004). Stress effects can lead to loss of work time or even to job loss (Hancock and Desmond, 2001).

Stress reactions vary, but they often include headaches, muscle tension, fatigue, insomnia, fuzzy thinking, and emotional or other problems (Rosa and Colligan, 1997). Stress can also increase the severity of already existing illnesses. Positive adaptive driver reactions to psychological stressors are important for maintaining good psychological health. Behaviorally, the driver's ability to cope with stress manifests itself in the way they respond to people around them. Drivers may respond in a friendly, pleasant, or jovial manner or by resorting to argumentative responses, including resorting to exhibitions of road rage. Commercial drivers must adopt stress alleviation and management techniques (Roberts and York, 2000). They must develop coping skills that enhance the brain and body's adjustment to stress. Obtaining a sufficient quantity of quality sleep, engaging in regular physical exercise, and decreasing caffeine intake all improve one's ability to deal with stress. Relaxation responses, breathing activities, meditation, and other similar efforts quiet the body's adrenaline storm from stress and neutralize stress responses. Drivers develop stress hardiness to welcome new challenges, take on commitment, learn to have realistic expectations, and to be in control (see *Gettin' in Gear Wellness and Health Program*, Roberts and York, 2000; Krueger, 2002).

Mental Health: Depression and Adjustment Disorders

FMCSA 49 CFR 391.41 (b) (9) says that a person is qualified to drive a CMV if that person has no mental, nervous, organic, or functional disease or psychiatric disorder likely to interfere with the ability to drive a CMV safely. The regulations go on to say that emotional or adjustment problems contribute directly to an individual's level of memory, reasoning, attention, and judgment. These problems often underlie physical disorders. A variety of functional disorders can cause drowsiness, dizziness, confusion, weakness, or paralysis that may lead to a lack of coordination, inattention, loss of functional control and susceptibility to crashes while driving. Physical fatigue, headache, impaired coordination, recurring physical ailments, and chronic nagging pain may be present to such a degree that certification for commercial driving is inadvisable. FMCSA further states that somatic and psychosomatic complaints should be thoroughly examined when determining an individual's overall fitness to drive. Disorders of a periodically incapacitating nature, even in the early stages of development may warrant disqualification. (See the report on the Conference on Neurological Disorders and Commercial Drivers, and the Conference on Psychiatric Disorders and Commercial Drivers at www.fmcsa.dot.gov/rulesregs/medreports.htm).

In their TRB-sponsored synthesis study of safety practices, Knipling, Hickman, and Bergoffen (2003) cited National Institute of Mental Health figures indicating about 22% of adult Americans suffer from a diagnosable mental disorder. Major disorders include depression, other mood disorders, and anxiety disorders such as panic disorder and obsessive–compulsive neurosis. In the survey work of Knipling et al. with the commercial truck and bus industry, these mental health problems were not perceived by carrier safety managers and other survey respondents to be as important as other topics in their safety management arena with commercial drivers.

No other mental health-related studies nor citable data concerning the mental health of commercial drivers were located for inclusion in this section. Nevertheless, depression and other mental health adjustment disorders can be serious health threats and can have implications for highway safety.

Sleep Disorders and Commercial Truck Drivers

Sleep disorders can deprive drivers of much-needed quality and quantity of restful, restorative sleep. Sleep disorders often lead to driver fatigue and loss of alertness while driving and thereby can negatively affect driving safety. Several sleep disorders are particularly important to commercial drivers. Among these are insomnia, sleep apnea, drug-dependency insomnia, restless leg syndrome (RLS), delayed or advanced sleep phase syndrome, and narcolepsy.

Insomnia usually is associated with various psychological and neurological effects that make it difficult for one to obtain enough quality sleep. Insomnia is a broad term used to describe abnormal sleeping problems such as inability to fall asleep readily or once asleep, being unable to remain asleep, or waking up too early from an intended sleep. Most people occasionally experience insomnia-related problems. Such problems become disorders when they occur with abnormal frequency or regularity and when they affect performance on the job (Morin, 1993). One of the most obvious and predictable factors with insomnia is its relationship to age. Sleep patterns become less consistent as we grow older, and thus insomnia is a more frequently occurring problem as people age (Coren, 1996).

Sleep apnea can be a principal cause of insomnia and has been repeatedly identified not only as a health threat but as an important cause of commercial driver sleepiness, leading to impairments in driving performance and potentially to vehicle crashes. Apnea means the absence of respiration; a person with sleep apnea literally stops breathing for anywhere from 10 s to 2 or 3 min. The person then awakens, may thrash around, gasp for air a few times, and fall asleep again and is not likely to remember the short awakenings when finally getting out of bed. Individuals with obstructive sleep apnea frequently are unaware of the presence of this condition. Apnea can profoundly disrupt sleep. Mostly a person with obstructive sleep apnea has frequent short bouts of the lighter Stage 1 and Stage 2 sleep, interrupted by short awakenings (of which the person is unaware) but does not obtain adequate amounts of Stage 3 and 4 deeper sleep. Consequently, even after having been in bed 6 to 7 h the person feels tired the next day. Apnea events disrupt natural breathing, and can result in as much as a 50% reduction in blood oxygenation levels. Sometimes sleep apnea accompanies cardiovascular illness, and the two in combination can lead to deadly consequences for the sufferer. Some such victims have died in bed of an arrhythmia or heart attack during bouts of sleep apnea.

It has been estimated that 4% of middle-aged male CMV drivers have some form of sleep apnea (Young et al., 1993). Studies of noncommercial drivers found sleep apnea to be associated with a statistically increased risk of crash involvement (Stutts, 2000). Stoohs et al. (1993, 1994, and 1995) identified fairly high prevalence rates of driver apnea and pointed out that the high rates of apnea were related to crashes of commercial trucks. With a concern for the incidence and effects of apnea on commercial drivers, FMCSA commissioned researchers at the University of Pennsylvania Hospital to perform a more comprehensive study of the prevalence of sleep apnea in commercial truck drivers. The study of Pack, Dinges, and Maislin (2002) involved 1,000 CMV drivers and included overnight laboratory testing of more than 400 drivers in Pennsylvania. In one of the largest apnea studies ever conducted on any population, Pack, Dinges, and Maislin found definitive indications of mild sleep apnea occurred in 17.6% of CDL holders, moderate sleep apnea in 5.8%, and severe sleep apnea in 4.7% of CDL holders—rates thought to be similar to sleep apnea rates in the overall U.S. male population.

Pack, Dinges, and Maislin (2002) reported that shorter average nightly sleep duration is associated with higher prevalence and severity of apnea. Decrements in performance and excessive sleepiness were found in individuals with severe sleep apnea and in those sleeping less than 6 h per night. Pack, Dinges, and Maislin (2002) also documented that sleep apnea prevalence increases with age, and with the degree of obesity as measured by BMI.

The problem of the high incidence of obesity accompanying sleep apnea in commercial truck drivers is a warning of both a health and a safety concern. In surveying almost 3,000 truck drivers attending a trade show, Korelitz et al. (1993) noted that 73% of them were either overweight (BMI between 25 and 30) or were obese (BMI >30). Stoohs et al. (1993) reported the prevalence of sleep apnea in 125 drivers working for one company they surveyed, and of those drivers who had sleep apnea, 71% also were classified as obese (i.e., BMI >28).

To understand further the impact of sleep apnea and driver impairment on crash involvement, Barr, Boyle, and Maislin at the Volpe National Transportation Systems Center studied the data from the more than 400 truck drivers in the Pack, Dinges, and Maislin (2002) study, the majority of whom were local and short-haul operators. Barr, Boyle, and Maislin (2004) attempted to link the sleep apnea database to that of the FMCSA MCMIS. Analyses showed that drivers diagnosed with sleep apnea had no greater likelihood of having a crash, or multiple crashes, than drivers without sleep apnea. A limitation of this study, however, was that it did not control for mileage exposure, which can vary widely among CDL holders. Only age (older than 45 years old) was found to be associated with both sleep apnea and the occurrence of crashes during the drivers' prediagnosis period (Barr et al., 2004). Thus this reassessment of a large set of data from commercial drivers with and without sleep apnea seems to contradict other findings (e.g., Stoohs et al., 1993) and prompts the scientific and safety communities to continue to conduct additional research along these lines.

To screen commercial drivers for obstructive sleep apnea, Gurubhagavatula et al. (2004) used polysomnography as the criterion standard and then prospectively compared the accuracies of five strategies in excluding the presence of severe sleep apnea and, secondarily, any sleep apnea among the 406 commercial drivers in the UPENN Study. The five strategies were

1. Symptoms;
2. BMI;
3. Symptoms plus BMI;
4. A 2-stage approach with symptoms plus BMI for everyone, followed by oximetry for a subset; and
5. Oximetry for all.

The two-stage strategy was highly successful for excluding severe apnea, with 91% sensitivity and specificity and a negative likelihood ratio of 0.10. This strategy was comparable in accuracy to oximetry, which had a negative likelihood ration of 0.12 and was 88% sensitive and 95% specific. Excluding apnea could not be done with reasonable accuracy unless oximetry was used. It was concluded that the two-stage screening was likely to be a viable means of excluding severe sleep apnea among commercial drivers.

Drug-dependency insomnia occurs as a side effect of overusing sleeping pills. The body adapts to the chemicals in sleeping pills, requiring higher and higher doses to get the same effect. Abrupt withdrawal from the medications causes sleep difficulties to become worse, above and beyond baseline levels (Gillian, Spinweber, and Johnson, 1989). One recovers from drug-dependency insomnia only after weeks or months of being drug free and attempts to stabilize both one's work and rest–sleep schedule.

RLS is a feeling of discomfort, often a tingling (pins-and-needles feeling), and sometimes severe, in the lower legs and an aching sensation in the calves, accompanied by an irresistible urge to move the legs. RLS may involve the thighs, feet, knees, and even the arms. RLS prevents a person from getting to sleep or staying asleep. It is more common in older people (age 65 and older), and it often accompanies apnea. Sufferers attempt to relieve RLS by kicking or stimulating the legs by walking or stretching. RLS and a related disorder called periodic limb movement disorder during sleep can be treated successfully (Montplaisir and Godbout, 1989).

Phase delay (or advance) syndrome delays the major sleep period in relation to its desired timing. It is characterized by intractable difficulty in falling asleep until late in the night (e.g., 3 a.m.) and it produces something like a portable "jet lag," as the sufferer experiences the effects similar to those in jet lag without going anywhere. It usually means sleeplessness at night, and sleepiness in the daytime (Morin, 1993). Long-term shift-work schedules, including night and swing shifts, can induce phase delay syndrome. The resultant shift lag problem can sometimes be corrected by forcing 3-h delays in sleep onset by going to sleep or staying awake later on successive nights until the body's circadian cycle is reset. Sometimes this shift lag condition is a side effect of emotional depression. The truck driving profession, with its frequently changing work schedules for many drivers, is highly likely to bring about numerous cases of delayed or advanced sleep phase syndrome. The likelihood of the incidence of this sleep disorder in the CMV driver community warrants more research.

Narcolepsy is characterized by a sudden, involuntary urge to sleep—transient, overpowering attacks of sleepiness usually lasting from a few seconds up to 30 min. The result is a literal sleep attack, even in the middle of a conversation, and it can last for as long as a 2- to 5-min duration, often without narcoleptics knowing this is happening, even though it is obvious to fellow conversationalists in front of them. Narcoleptics may have up to 200 such sleep attacks in a single day, even if they have slept well the night before. Narcolepsy has physical, not psychological, causes, and it results from a variety of conditions. Narcolepsy is thought to arise from a biochemical imbalance or defect in the central nervous system, one that affects the mechanism that activates the on–off cycle of sleep. There clearly is a hereditary factor in narcolepsy, as those who report a family history of the disorder are 60% more likely to develop it than other people (Sweeney, 1989).

One of the most prominent and troubling features of narcolepsy is a muscle paralysis condition called cataplexy—an attack of muscle weakness or dysfunction lasting from a few seconds to a few minutes. Cataplexy symptoms distinguish narcolepsy from other forms of hypersomnia. During a narcoleptic attack the victim's jaw may grow slack, or the head may drop forward onto the chest. In some cases victims may completely black out, appearing to be asleep or unaware of their actions. In less severe attacks, they are alert but may experience some form of muscle paralysis—their knees may buckle, or they may lose all control over their voluntary muscles. In some severe cases, narcolepsy can be life threatening. A person with narcolepsy who has been deprived of a significant amount of quality sleep (especially missing REM dreaming sleep) can become extremely sleepy while driving, and this could lead to crashes. Narcolepsy's real danger is a total collapse to sleep brought on by sudden emotional changes. This total collapse is not an urge to sleep, but rather an incapacitation. A person who has a serious case of narcolepsy should not drive or operate hazardous machinery until receiving treatment, usually with medications (Hauri and Linde, 1991).

Sleep disorders are of concern for the medical and health conditions associated with the maladies themselves; sleep apnea, for example, presents independent health risks. For commercial driving safety, however, most concern is with the resultant driver fatigue and the adverse affects on commercial driver alertness while operating trucks, buses, and motor coaches on the road. Sleep disorders, such as sleep apnea, are diagnosable, treatable, and, for the most part, manageable for commercial drivers. Consequently, FMCSA has contracted with the National Sleep Foundation (www.sleepfoundation.org) to develop an education and outreach program to inform the motor carrier industry of the problem of sleep apnea and other sleep disorders, and to tell them how they can address sleep orders effectively. For more details on qualification and disqualification of drivers regarding sleep disorders, see the FMCSA website at www.fmcsa.dot.gov.

Motor carriers have become more aware of sleep disorder issues and have begun to develop countermeasures. Motor carrier perspective on sleep disorders has changed in the past decade. Previously trucking companies simply terminated employment of drivers with sleep maladies. Now, however, proactive trucking firms are determining ways to provide medical screening for sleep disorders and providing for diagnosis and treatment. The goal is to retain their valuable experienced drivers even while they are in treatment for some of the sleep maladies discussed above. As a part of their in-house driver-fatigue management programs, some enlightened commercial freight carriers have implemented sleep disorder–screening procedures, as well as medical referral and evaluation at sleep disorder clinics.[3]

Driver Fatigue as a Function of Long Work Schedules

Medical and health aspects of operator fatigue include considerations of quantity of sleep and quality of sleep obtained on a regular basis; of sleep disruption, sleep deprivation, and chronic sleep loss; rotating shift work and extended work schedules (extensively long work hours either per day or per week); sleep disorder screening and treatment; and the development and adherence to sleep discipline programs. This health and wellness chapter covers only a few of the direct and indirect health issues associated with driver fatigue, shift work, and extensively long hours of work. More coverage of driver fatigue appears in this circular in the section on human factors.

The current generation of research on HOS, driver fatigue, and driver safety began in 1989. Spurred on by prompts from NTSB, and an influx of research funding from the Senate Transportation Subcommittee, a significant amount of government- and industry-sponsored safety research has focused on commercial driver fatigue, health, and wellness. Almost all of that research on commercial driver fatigue and alertness was done with truck drivers. It seems, as a class, commercial motorcoach and bus drivers have not been a focus of study (Brock et al., 2005). Many of the truck driving research projects and the results of each are available on the FMCSA website at www.fmcsa.dot.gov.

The most recent series of efforts to revise the commercial driver HOS regulations began in 1996—a U.S. DOT advance notice of proposed rule making was published in November 1996. For more than a decade, government personnel, trucking safety specialists, and highway safety advocates devoted considerable efforts toward establishing new HOS rules for commercial drivers in the hopes that new rules formed around the new research results would help diminish incidents of fatigued-driver crashes.

In April 2003, FMCSA announced a new set of HOS rules for commercial truck drivers (but not for bus and motor coach drivers) and these went into effect in January 2004. The new truck driver HOS rules increased the off-duty time from a minimum of 8 to a minimum of 10 continuous hours, increased the driving time limits from 10 to 11 h, decreased the period of time after which driving is prohibited from 15 h (which could be broken up with off-duty periods) to a 14-h limit from the beginning of the work shift, and revised the regulations to incorporate a 34-h "restart" the consecutive 7- or 8-day period provision rather than a strict 7- or 8-multiday limit of on-duty time. The HOS regulations can be found on the FMCSA website at www.fmcsa.dot.gov.

Significantly for this particular chapter on driver health and wellness, the U.S. Court of Appeals vacated, or set aside, those new HOS rules in July 2004, essentially stating that FMCSA did not properly account for commercial drivers' health consequences when formulating the new HOS rules. The U.S. Congress directed FMCSA to publish a new rule, which FMCSA did in August 2005 (see FMCSA website, 49 CFR, Part 395) addressing those concerns. The August 2005 HOS rules sustained the January 2004 HOS rules, with only slight modifications, particularly affecting sleeper-berth operations.[4]

Some health issues contested over the new HOS included the following:

1. Whether or not permitting drivers to drive for 11 straight hours, in place of the previous limit of 10 h, affects driver health. Arguably it can impact driver alertness, drowsiness,

and fatigue, but depending upon one's perspective of effects on health, the evidence is not so clear (e.g., health implications attributable to additional exposure to diesel fumes, whole body vibration, more or less stress).

2. Whether drivers are discouraged from stopping their long drives to take long rest breaks or naps, which by the new rules would impact their legal hours of driving on their logs—and whether or not that impacts driver fatigue and health.
3. Whether drivers spend more time working during a week, or in consecutive hours of driving under the new HOS rules, and does this impact health and performance.
4. Whether the 34-h restart features are related to more driving hours and health.
5. Whether or not limiting drivers to 14 h on duty followed by 10 h off duty for a daily work schedule, permits drivers actually to obtain more daily sleep and thereby increase the chances of synchronizing their body's circadian physiological rhythms than they could under the previous rules and therefore net an improvement in health consequences.

There is some evidence that drowsy drivers experience frequent and extended periods of eyelid droop or even periodic eyelid closure while driving fatigued. The premise behind developing eyelid droop monitoring devices, such as in-vehicle camera systems that yield a percent of eye closure (PERCLOS) measurement of the amount of eye closure a driver experiences, was based upon a belief that driver alertness could be monitored, fatigue detected, and status warnings could be provided to sleep drivers (Wierwille, 1999). Further, since the effects of fatigue may be cumulative, innovative research will be required to determine the effects of an extra hour of driving on trucker performance, much less the effects on health. NIOSH, FMCSA, and independent researchers are conducting or planning relevant studies (for current research programs on these topics, see the FMCSA website at www.fmcsa.dot.gov).

There are many personal health-related implications and facets to examining alternative work and rest schedules, shift work schedules, etc. It is not a goal of this chapter to address them here, as space would not permit us to do justice to the myriad of topics. The shiftwork book by Scott (1990) goes into considerable detail on many of these important worker-related health topics, as does the literature review of Orris et al. (2005) on both driver fatigue and wellness issues. Notions of the literally hundreds of alternative work shift schedules experienced in the United States and European industrial workplaces are covered in some detail in Tepas (1999) and in Tepas, Paley, and Popkin (1997). Likewise, research on the many facets of workload, stress, and fatigue are described in great detail in the book by Hancock and Desmond (2001). Caruso et al. (2004) provide a more current examination of the effects of overtime and extended work shifts on illnesses, injuries, and health behaviors. Wylie's (2005) editorial on sleep, science, and policy change noted that sleep debt and circadian rhythms, associated with irregularity of sleep, food, recreation, and exercise, are likely to affect drivers. Barger et al. (2005) found that extended work shifts doubled the risk (odds ratio) of a motor vehicle crash and also increased the risk of near-misses and falling asleep.

While further studies of commercial driver fatigue as it relates to health are needed, such studies require time, numerous resources, and ingenuity to complete. In the meantime, it is generally believed that the overall lifestyle required by extended trucking hours may have a negative impact on driver health, wellness, and performance. Improvements in diet, exercise, sleep, and health care should be encouraged and facilitated; and more research on the relationships among driver lifestyle, health, and performance is needed.

Consideration of the broader affects of driver fatigue and driver performance and safety is covered in this circular in the section on human factors.

MEDICAL CONDITIONS AND FUNCTIONAL IMPAIRMENT: A CRITICAL DISTINCTION

Few empirical studies directly relate the drivers' physical conditions outlined in this chapter to actual driving performance or crash involvement. The concern is whether such conditions contribute substantially to reduced performance, and therefore to highway safety (Knipling et al., 2003; Staplin and Lococo, 2003). More holistic research that examines driver health issues in the context of their jobs is needed.

Discussions about fitness to drive historically focused on various medical conditions that can impair the ability to safely control a motor vehicle. This is understandable, considering that physicians—the final arbiters in this arena—perform medical diagnoses, not driving assessments. But in 1999 the Council on Ethical and Judicial Affairs of the American Medical Association (AMA, 1999) published a report articulating physicians' responsibility to recognize impairments in patients' driving ability that pose a threat to public safety and, when clearly documented, to notify the department of motor vehicles in their state. That report emphasized that a physician must be able to identify and document physical or mental impairments that clearly relate to the ability to drive. A key distinction here is that between functional ability and medical diagnosis. Cardiac arrhythmias may cause syncope; until the condition is controlled, the result is an impaired driver. Uncontrolled diabetes may cause loss of consciousness and therefore an impaired driver. Peripheral neuropathy from uncontrolled diabetes may cause a decrease in reaction time, which also is unacceptable for safe driving. However, restoring diabetic control and instituting physical therapy may return this individual to safe driving for some indefinite time period. The detection of driving impairments must be keyed to the loss of functional ability, not the diagnosis of a medical condition per se. In other words, it is not the condition an individual is diagnosed with that is most directly related to fitness to drive, it is the impact of that condition on the visual, cognitive, and physical abilities that are essential to safely control a motor vehicle.

Occupational medicine physicians have long requested explicit guidance about the degree of driving impairment that will result from a particular stage of a given disease—for example, diabetes—but scientific information to support such guidance has generally been lacking. There is hope that emerging research findings now can focus attention upon a limited set of functional abilities that significantly predict at-fault crash risk, and guide practitioners in how to measure them (Staplin and Lococo, 2003). A case-control study sponsored by NHTSA pinpointed a small number of physical and cognitive abilities that, if impaired due to disease, trauma, or simply the effects of normal aging, result in a 2- to 5-times increase in the risk of causing a crash (Staplin, Gish, and Wagner, 2003). These physical and cognitive abilities included various aspects of vision and visual attention, divided attention, and working memory and cognitive processing, used in wayfinding, use of vehicle displays and navigational devices, reaction time, head and neck mobility, flexibility and range of motion of extremities, and others.

This recognition of functional impairment as a possible gold standard in a clinical determination of fitness to drive has clear implications for CMV operations. As valid, reliable, and affordable techniques for screening an operator's driving health come online, not only physicians, but fleet safety managers will gain valuable new tools to assure themselves and the public that reasonable safeguards are in place to advance health and wellness in the trucking and motor coach industries. This topical area is ripe for further research and safety-related discussion.

WELLNESS PROGRAMS AND COMMERCIAL DRIVERS

There are other additional common health risks to drivers that relate to fitness for CMV driving and safety. Hypertension, obesity, diet and nutrition, smoking, respiratory dysfunctions (e.g., emphysema, asthma), physical fitness or lack thereof, etc. (24-h per day, not just at work), are all related to driver health and wellness and insofar as they affect driving safety, are of concern in this chapter. TRB Synthesis studies done on transit drivers (McGlothin Davis, 2002; Davis, 2004) indicated operators who are healthy and have a solid sense of well being are best equipped to fill the varied roles of the transportation industries. Operator health and wellness issues not addressed or acted on can affect safety, service, absenteeism, employee turnover, and workers' compensation in costly and negative ways. Conditions of concern for both the transit and the over-the-road commercial truck and bus drivers include stress, hypertension, heart disease, mental health issues, stroke, back- and neck-related injuries, obesity, diabetes, tobacco use, and alcohol and other drug-related problems. In addition, family-centered issues may affect an operator's overall health and wellness (Davis, 2004).

Truck and motor coach driving are largely sedentary in nature, with few opportunities for drivers to exercise. Exercise can help combat driver fatigue, reduce stress, improve alertness, and enhance sleep. To encourage drivers to obtain more regular physical exercise, FMCSA and the American Transportation Research Institute (ATRI) explored possibilities of establishing fitness facilities at a small number of truck stops (Robin and Roberts, 1999). Although this program offered some promise for improving driver fitness, for several practical reasons it did not prove to be financially viable, and it was not continued beyond the initial trials.

It is generally assumed that establishing wellness consciousness and adopting a health-oriented lifestyle can make a person a more attentive driver who is more likely to adhere to safe driving practices (Krueger, Brewster, and Alvarez, 2002). Obviously transportation safety researchers and the commercial transportation community in general would like to know if this presumption is verifiable and, if so, to what degree? It gets to the crux of why companies might or might not encourage health and wellness programs among their drivers.

For the decade of the 1990s, the commercial trucking industry wrestled with issues of recognizing the important role that driver health and wellness plays in driver safety, performance, job satisfaction, and industry competition. There were various individual program efforts on these topics among industry organizations like the ATA, the National Private Truck Council (NPTC) and the Owner–Operator Independent Drivers Association (OOIDA). The few instances of wellness programs implemented in the transit industry were not systematically identified until the TCRP studies of McGlothin Davis (2000) and Davis (2004). In 1997, FMCSA began a research project to design, develop, and evaluate a model truck and bus driver wellness program. The research was completed by Roberts and York (2000) at NPTC, and the results led to the development of the Gettin' in Gear (GIG) Program to provide heightened awareness and interest in driver health and wellness.

The GIG project included a review of the scant literature available on current programs concerning driver health and wellness. Roberts and York conducted a survey of 448 experienced, mostly long-haul drivers, who showed that insufficient family time, lack of exercise, personal body weight, poor diet, sleep loss, and fatigue were their priority health and wellness concerns. Very few trucking companies have wellness programs so a core wellness program was prepared for FMCSA. The GIG project recruited CMV drivers and other industry personnel to participate directly in the development of the program. In a pilot test trial of the program, educational and motivational materials on basic health and fitness information were distributed to people in the truck and bus industries. The GIG Program had a positive health impact on the participants, both initially and at the time of follow-up. This was shown in both lifestyle habits (e.g., exercising, resting, eating balanced meals) and physical lifestyle data (e.g., BMI, pulse, diastolic blood pressure, aerobic, strength, and fitness levels).

From the core GIG wellness program, FMCSA subsequently contracted with ATRI to develop a train-the-trainer course entitled Gettin'-in-Gear: Wellness, Health, and Fitness for Commercial Drivers (Krueger, 2002). FMCSA and ATRI offered such training to the trucking industry from October 2002 through the midyear 2005: the GIG train-the-trainer class was conducted more than 25 times around the United States. The training was offered as a companion program in conjunction with the driver fatigue awareness course entitled Mastering Alertness and Managing Commercial Driver Fatigue. More than 500 people attended the GIG health and wellness training courses, and more than 4,500 attended the alertness course taught more than 95 times between 1996 and 2006. Most attendees have been trucking industry risk-and-safety managers, with some participation by health and occupational medicine specialists working in large trucking firms across the country (Krueger, Brewster, and Alvarez, 2002; Krueger and Brewster, 2005).

For expansion of the topic of driver alertness and fatigue, the reader might consult the helpful list of 26 ABCs of *What We Know About Commercial Driver Fatigue* and *What We Are to Do About It* (Krueger, Brewster, and Alvarez, 2002). Some other proactive programs in driver fatigue management (Moscovitch, Wartman, et al., 2004; Holmes, Power, and Walter, 1996; McCallum et al., 2003) involve many wellness and health tenets, such as screening for sleep maladies and advocating driver wellness-consciousness lifestyles including diet, nutrition, and exercise.

HEALTH- AND WELLNESS-RELATED RESEARCH NEEDS

Information on truck and motorcoach driver health and wellness is scarce and uneven. Truckers in particular tend to be a unique group with a strong sense of individuality and independence. At the same time, work demands of both truckers and motorcoach drivers make it difficult for many to have regularly coordinated lives in the sense that workers in other industries enjoy. Scheduling demands and the limitations of available facilities present potential obstacles to healthy lifestyle in terms of diet, exercise, rest, and social relationships. Most of the interest in trucking to date has been focused on the large number of fatal crashes involving commercial trucks. Relatively little research has focused on such potential issues as musculoskeletal problems related to slips, trips, falls, and sprains associated with ingress and egress from vehicles. Such nonfatal injuries are a major contributor to worker's compensation costs in the trucking industry. Lack of physical conditioning due to a largely sedentary job may well aggravate this problem. Relatively little information and guidance has been disseminated to encourage trucker wellness or fitness. A notable exception is the GIG training program sponsored by ATRI and FMCSA.

Studies of other occupational groups have been relatively straightforward because researchers can make contact at a fixed place of work, often through management. Some establishments have a designated medical or safety professional who can expedite and encourage studies of health and wellness. One of the few places that truckers can be contacted is at truck stops and some researchers have adopted this strategy to get a convenience sample of interviews. Some groups, such as OOIDA provide a sounding board and a central contact. NIOSH is funding a collaborative study of causes of mortality in deceased OOIDA members (Husting et al., 2005). This study may determine whether or not these drivers experience early mortality from CVD or other chronic health effects. However, further studies will likely be needed to understand the causes of any patterns that may emerge. In an examination of medical records of long-haul truck drivers, Robinson and Burnett (2005) reported drivers who died before age 55 had high mortality rates from lung cancer, and they recommended that longitudinal studies of drivers be conducted to explain such results.

An increasing number of truckers have their vehicle as their primary address, and are, in effect, living on the road. Female truckers face special demands and preliminary results (Debra G. Anderson, University of Kentucky, Lexington, May 2005, personal communication) suggest that many fear or actually encounter violence and lack ready access to health care. Solomon et al. (2004) conducted a cross-sectional survey and found that almost half of long-haul truckers reported not having a regular healthcare provider. They note that "long-distance drivers are at risk for poor health outcomes and experience difficulty accessing healthcare services." They conclude that further studies are needed.

The July 2004 decision of the U.S. Federal Court, in overturning the HOS that became effective January 4, 2004, effectively set a research agenda for the health and safety community that is based on long-standing legal requirements. The findings point to the fact that there is a shortage of research findings on the effects of these HOS rules on CMV driver health. This section has articulated both research evidence and gaps in the available research for the health and safety community to pursue.

There are, of course, inherent problems in conducting epidemiological or other studies of these issues. Unlike measurable exposures to chemical or physical hazards, exposure to different HOS patterns is very difficult to measure, especially across groups of workers. While there is substantial research on the health effects of fatigue in other occupations (Scott, 1990; Caruso et al., 2004), little has been done directly with truckers or with bus or motorcoach drivers (Brock et al., 2005).

As is evident in the section of this report on health and wellness programs, not much is known about the extent to which commercial transportation firms have already implemented any form of employee (driver) health and wellness programs. A survey of the good and successful ones might shed light on how to produce such programs successfully on a larger scale. At this writing, a TRB truck and bus synthesis study is under way to address this question.

In addition to the need for further research on some of the topics described in each of the separate sections above, additional research needs related to health and wellness of commercial truck and bus drivers can be considered as they might be involved in safety issues. These research needs can be identified from a variety of sources including those described by attendees at FMCSA's Office of Research and Technology Stakeholder Forums (2003, 2004) and FMCSA's Science and Technology 5-Year Strategic Plan, in the health and wellness review at the TRB Truck and Bus Safety Research Opportunities Conference (Husting et al., 2005), and by participants in the April 2003 Truck Driver Occupational Safety and Health Conference, in Detroit, Michigan (Saltzman and Belzer, 2003; www.ilir.umich.edu/tibp/truckdriverosh).

CDL MEDICAL EXAMINATIONS

Participants in the FMCSA 2003 stakeholder meetings pointed out the need for conducting research and analyses into the importance, relevance, and certification criteria and also the processes related to having regularly scheduled CDL physical qualifying examinations. They pointed out the need for greater consistency between FMCSA medical guidelines and current medical research and practice. In one recent resulting initiative in 2004, FMCSA brought the hypertension standards in 49 CFR 391.41 (b) (5) into conformance with those of the AMA and the World Health Organization.

In 2005 FMCSA began work on a number of such health-related issues, beginning with forming a medical review board, a panel to review all the medical regulations and criteria in 49 CFR Part 391.4 and to provide science-based guidance to establish improved medical standards as FMCSA updates physical qualification regulations of CMV drivers. It is anticipated that many of the current regulations will be changed over the next few years. Additionally, FMCSA is working on credentialing medical practitioners to perform driver CDL medical exams, to develop a register of certified individuals to perform such exams, and to develop a standard curriculum to train medical personnel on how to conduct a CDL-qualifying medical exam. To clarify some misunderstandings with educational outreach initiatives, recently FMCSA made it clear that a medical examiner does not have to certify or approve a CMV driver for 2 years if he/she has concerns that the medical condition of a driver is changing or if treatment compliance on the part of the driver is questionable.

In summary, more research is needed on driver health and wellness issues that relate to commercial driver safety and health. Identifying those research needs could begin with preparation of a comprehensive health and wellness review, including an extensive bibliography, and an identification of where the gaps in our knowledge lie. This could facilitate a prioritized research plan involving various government agencies and industry to address the most important gaps. Such a review would also help both researchers and practitioners to understand better the driving safety implications of the numerous issues outlined in this chapter.

ACKNOWLEDGMENTS

The authors gratefully acknowledge the thoughtful comments and critique of early drafts of this chapter by the following individuals: Howard Leaman, Intermountain Health Care, Salt Lake City, Utah; Kathryn Clements of the Healthy U, Cannon Falls, Minnesota; and Martin Walker and Deborah Freund of FMCSA.

NOTES

1. METS = multiples of the resting metabolic rate; 6 METS is a medium work level, which could include carrying moderate weight objects up to 50 lb—akin to most truck driving workloads; see McArdle, Katch, and Katch, 1991.
2. This exception does not apply to the use of methadone.
3. Personal communication with G. P. Krueger; for the past decade he has traveled about the country lecturing to trucking firms on driver alertness, fatigue, health and wellness and interacting with them about their programs, March 2006.
4. U.S. Court of Appeals for the District of Columbia Circuit. No. 03-1165*: Public Citizen et al., Petitioners vs. Federal Motor Carrier Safety Administration*. See also the explanatory text of the January 24, 2005, notice of proposed rulemaking.

REFERENCES

American Medical Association Council on Ethical and Judicial Affairs, December 1999. *Impaired Drivers and Their Physicians.* AMA Code of Medical Ethics No. E-2.24. Available at www.ama-assn.org.

Babkoff, H., and G. P. Krueger. Use of Stimulants to Ameliorate the Effects of Sleep Loss During Sustained Performance. DTIC No. AD:A259-712. *Military Psychology*, Vol. 4, 1992, pp. 191–205.

Ball, K. K., C. Owsley, M. E. Sloane, D. L. Roenker, and J. R. Bruni. Visual Attention Problems as a Predictor of Vehicle Crashes in Older Drivers. *Investigative Ophthalmology and Visual Science*, Vol. 34, 1993, pp. 3110–3123.

Barger, L. K., B. E. Cade, N. Ayas, et al. Extended Work Shifts and the Risk of Motor Vehicle Crashes Among Interns. *New England Journal of Medicine*, Vol. 352, 2005, pp. 125–134.

Barr, L. C., L. Boyle, and G. Maislin. Sleep Apnea Crash Risk Study. FMCSA Tech Brief Publication No. FMCSA-RT-04-007. Office of Research and Technology, FMCSA, U.S. Department of Transportation, 2004.

Belkic, K., C. Savic, T. Theorell, I. Rakic, D. Ercegovac, and M. Djordjevic. Mechanisms of Cardiac Risk Among Drivers. *Scandinavian Journal of Work Environmental Health*, Vol. 20, 1994, pp. 73–86.

Bergoffen, G., R. R. Knipling, S. A. Tidwell, J. B. Short, G. P. Krueger, R. E. Indertitzen, G. Reagle, and D. C. Murray. *CTBSSP Synthesis of Safety Practice, No. 8: Commercial Motor Vehicle Driver Safety Belt Usage.* Transportation Research Board of the National Academies, Washington, D.C., 2005. Available at http://trb.org/news/blurb_browse.asp?id=11.

Bergonzi, P., C. Chuunvilla, and E. Tempesta. Selective Deprivation of Sleep Stages in Epileptics. In *Sleep: Physiology, Biochemistry, Psychology, Pharmacology, Clinical Implications* (W. P. Koella and P. Levin, eds.). 1st European Congress on Sleep Research, Kayer, Basil, Switzerland, 1973.

Bigert, C., P. Gustavsson, J. Hallqvist, C. Hogstedt, M. Lewne, N. Plato, C. Reuterwall, and P. Scheele. Myocardial Infarction Among Professional Drivers. *Epidemiology*, Vol. 14, No. 3, 2003, pp. 333–339.

Blumenthal, R., J. Braunstein, H. Connolly, A. Epstein, B. J. Gersh, and E. H. Wittels. *Cardiovascular Advisory Panel Guidelines for the Medical Examination of Commercial Motor Vehicle Drivers*. FMCSA Report No. MCP-02-002. FMCSA, U.S. Department of Transportation, 2002.

Brock, J. F., G. A. Golembiewski, G. P. Krueger, C. Daecher, R. Bishop, and G. Bergoffen. *CTBSSP Synthesis of Safety Practice, No. 7: Motorcoach Industry Hours of Service and Fatigue Management Techniques.* Transportation Research Board of the National Academies, Washington, D.C., 2005. Available at http://trb.org/news/blurb_browse.asp?id=11.

Burg, A. Vision and Driving: A Summary of Research Findings. *Highway Research Record 216*, HRB, National Research Council, Washington, D.C., 1968, pp. 1–12.

Burg, A. Vision and Driving: A Report on Research. *Human Factors*, Vol. 13, 1971, pp. 79–87.

Caldwell, J. A., and J. L. Caldwell. *Fatigue in Aviation: A Guide to Staying Awake at the Stick.* Ashgate Publishing Limited, Aldershot, Hants, England, 2003.

Caldwell, J. A., and J. L. Caldwell. Fatigue in Military Aviation: An Overview of U.S. Military-Approved Pharmacological Countermeasures. *Aviation, Space, and Environmental Medicine*, Vol. 76, No. 7, Supplemental Section II, 2005, pp. C-39–C-51.

Cann, A. P., A. W. Salmoni, and T. R. Eger. Predictors of Whole-Body Vibration Exposure Experienced by Highway Transport Truck Operators. *Ergonomics*, Vol. 47, No. 13, 2004, pp. 1432–1453.

Caruso, C. C., E. M. Hitchcock, R. B. Dick, J. M. Russon, and J. M. Schmit. *Overtime and Extended Work Shifts: Recent Findings on Illnesses, Injuries, and Health Behaviors*. DHHS (NIOSH) Publication No. 2004-143. Department of Health and Human Services, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, Cincinnati, Ohio, 2004.

Caruso, C. C., S. L. Lusk, and B. W. Gillespie. Relationship of Work Schedules to Gastrointestinal Diagnoses, Symptoms, and Medication Use in Auto Factory Workers. *American Journal of Industrial Medicine*, Vol. 46, No. 6, 2004, pp. 586–598.

Coeckelbergh, T. R. M., W. H. Brouwer, F. W. Cornelissen, and A. C. Kooijman. Predicting Practical Fitness to Drive in Drivers with Visual Field Defects Caused by Ocular Pathology. *Human Factors*, Vol. 46, No. 4, 2004, pp. 748–760.

COMS. *California Occupational Mortality 1979–1981*. Department of Health Services, Sacramento, Calif., 1987.

Comperatore, C. A., and G. P. Krueger. Circadian Rhythm Desynchronosis, Jet Lag, Shift Lag, and Coping Strategies. In *Occupational Medicine: State of the Art Reviews*, Vol. 5, No. 2, pp. 323–341. Also printed as USAARL Technical Report No. 90-14. (DTIC No. AD: A228-787). U.S. Army Aeromedical Research Laboratory, Fort Rucker, Ala., September 1990.

Conference Proceedings No. 38: Future Truck and Bus Safety Research Opportunities. Transportation Research Board of the National Academies, Washington, D.C., 2005.

Coren, S. *Sleep Thieves: An Eye-Opening Exploration into the Science and Mysteries of Sleep*. Free Press, New York, N.Y., 1996.

Czeisler, C. A., J. K. Walsh, T. Roth, R. J. Hughes, K. P. Wright, L. Kingsbury, S. Arora, J. R. L. Schwartz, G. W. Niebler, and D. F. Dinges. Modafinil for Excessive Sleepiness Associated with Shift-Work Sleep Disorder. *New England Journal of Medicine*, Vol. 353, No. 5, 2005, pp. 476–486.

Davis, M. J. *TCRP Synthesis of Transit Practice, No. 52: Transit Operator Health and Wellness Programs*. TRB, National Research Council, Washington, D.C., 2004.

Decina, L. E., and M. E. Breton. Evaluation of the Federal Vision Standard for Commercial Motor Vehicle Operators. In *Transportation Research Record 1421*, TRB, National Research Council, Washington, D.C., 1993, pp. 45–52.

DelPonte, A., F. Capani, A. Domani, and S. Sensi. Circadian Variation of Digoxin Effects in Healthy Subjects. In *Chronopharmacology: Proceedings of the 7th International Congress on Pharmacology* (P. A. Reinberg and F. Halberg, eds.). New York: Pergamon Press, 1979, p 135.

Dionne, G., D. Desjardins, C. Laberge-Nadeau, and U. Maag. Medical Conditions, Risk Exposure, and Truck Drivers' Accidents: An Analysis with Count Data Regression Models. *Accident Analysis and Prevention*, Vol. 27, No. 3, 1995, pp. 295–305.

FHWA. *Role of Driver Hearing in Commercial Motor Vehicle Operation: An Evaluation of the FHWA Hearing Requirement*. FHWA-OMC Tech Brief. Office of Motor Carriers, FHWA, U.S. Department of Transportation, November 1998.

FHWA. *Qualifications of Drivers: Vision and Diabetes*. FHWA-OMC Tech Brief. Office of Motor Carrier and Highway Safety, FMCSA, U.S. Department of Transportation, 1999.

FHWA. *Design, Development, and Evaluation of Truck and Bus Driver Wellness Programs*. FMCSA Tech Brief. Office of Research and Technology, FMCSA, U.S. Department of Transportation, 2000.

FMCSA. *Visual Requirements for Commercial Motor Srivers*. FMCSA Tech Brief, Publication No. FMCSA-MCRT-01-007. FMCSA, U.S. Department of Transportation, 2001.

FMCSA. *Qualifying Individuals with Insulin-Treated Diabetes to Operate Commercial Motor Vehicles*. FMCSA Tech Brief, Publication No. FMCSA-MCRT-02-001. Office of Research and Technology, FMCSA, U.S. Department of Transportation, 2001.

FMCSA. *A Study of Sleep Apnea Among Commercial Truck Drivers*. FMCSA Tech Brief, Publication No. FMCSA-RT-02-080. Office of Research and Technology, FMCSA, U.S. Department of Transportation, 2002.

FMCSA. *Results from the 2003 R&T Stakeholder Forums*. FMCSA, U.S. Department of Transportation, 2003.

Medical Advisory Criteria for Evaluation Under 49 CFR Part 391.41. FMCSA, U.S. Department of Transportation, 2004. Available at www.fmcsa.dot.gov/rulesregs/fmcsr/medical.htm.

FMCSA. *Report to Congress on the Large Truck Crash Causation Study*. DOT-FMCSA Technical Report No. MC-r/MC-RRA. Office of Research and Technology, FMCSA, U.S. Department of Transportation, 2006. Available at www.fmcsa.dot.gov.

Gillin, J. C., C. L. Spinweber, and L. C. Johnson. Rebound Insomnia: A Critical Review. *Journal of Clinical Psychopharmacology*, Vol. 9, 1989, pp. 161–172.

Gurubhagavatula, I., G. Maislin, J. E. Nkwuo, and A. I. Pack. Occupational Screening for Obstructive Sleep Apnea in Commercial Drivers. *American Journal of Respiratory Critical Care Medicine*, Vol. 170, No. 4, 2004, pp. 371–376.

Hancock, P. A., and P. A. Desmond. Stress, Workload, and Fatigue. In *Human Factors in Transportation* (B. H. Kantowitz, ed.). Lawrence Erlbaum Associates, Mahwah, N.J., 2001.

Harig, P., J. Halle, R. Mosier, J. Reagan, and M. Richardson. *Wellness for Senior Leaders, Taking Care of Yourself: A Proactive Approach.* U.S. Army War College, Army Physical Fitness Research Institute, Carlisle Barracks, Pa., 1995.

Hauri, P., and S. Linde. *No More Sleepless Nights*. Wiley and Sons, New York, 1991.

Hehakkanen, H. Fatal Traffic Accidents Among Trailer Truck Drivers and Accident Causes as Viewed by Other Truck Drivers. *Accident Analysis and Prevention*, Vol. 33, No. 2, 2001, pp. 187–196.

Holmes, S., M. Power, and C. Walter. A Motor Carrier Wellness Program: Development and Testing. *Transportation Journal*, Spring 1996, pp. 34–48.

Husting, L., M. Belzer, T. Hitchcock, L. Byrd, D. Osterberg, and M. Rosekind. Driver Health and Wellness. In *Conference Proceedings 38: Future Truck and Bus Safety Research Opportunities*, Transportation Research Board of the National Academies, Washington, D.C., 2005.

Husting, L., and E. A. Biddle. Truck Safety in the Age of Information. In *Trucking in the Age of Information* (D. Belman and C.White, eds.). Ashgate Publishing, London, 2005, pp 247–267.

Johnson, C. A., and J. L. Keltner. Incidence of Visual Field Loss in 20,000 Eyes and Its Relationship to Driving Performance. *Archives of Ophthalmology*, Vol. 101, 1983, pp. 371–375.

Kamimori, G. H., C. S. Karyekar, R. Otterstettere, D. S. Cox, T. J. Balkin, G. L. Belenky, and N. D. Eddington. The Rate of Absorption and Relative Bioavailability of Caffeine Administered in Chewing Gum Versus Capsules to Normal Healthy Volunteers. *International Journal of Pharmaceutics*, Vol. 234, 2002, pp. 159–167.

Kelly, E., S. Darke, and J. Ross. A Review of Drug Use and Driving: Epidemiology, Impairment, Risk Factors and Risk Perceptions. *Journal of Drug and Alcohol Review*, Vol. 23, No. 3, 2004, pp. 319–344.

Knipling, R. R., J. S. Hickman, and G. Bergoffen. *CTBSSP Synthesis of Safety Practice 1: Effective Commercial Truck and Bus Safety Management Techniques.* Transportation Research Board of the National Academies Washington, D.C., 2003.

Korelitz, J., et al. Health Habits and Risk Factors Among Truck Drivers Visiting a Health Booth During a Trucker Trade Show. *American Journal of Health Promotion*, Vol. 8, No. 2, 1993, pp. 117–123.

Krueger, G. P. *Gettin'-in-Gear Wellness, Health, and Fitness Program for Commercial Drivers: Instructors Manual.* American Transportation Research Institute, Alexandria, Va., 2002.

Krueger, G. P., and R. M. Brewster. Commercial Driver Wellness, Health and Fitness: A Program for Mastering Driver Alertness and Managing Fatigue. *Proc., International Conference on Fatigue Management in Transportation*, Seattle, Wash., 2005.

Krueger, G. P., R. M.Brewster, and A. Alvarez. Gettin'-in-Gear: Commercial Driver Training Program for Wellness, Health, and Fitness: Precursors to Mastering Driving Alertness and Managing Driver Fatigue. In *Proc., International Truck and Bus Safety Research and Policy Symposium* (Z.G. Zacharia, ed.). Center for Transportation Research, the University of Tennessee, Knoxville, 2002, pp 127–144.

Krueger, G. P, and S. B. Van Hemel. *Effects of Loading and Unloading Cargo on Commercial Truck Driver Alertness and Performance.* FMCSA Technical Report No. DOT-MC-01-107. FMCSA, U.S. Department of Transportation, 2001.

Kushner, R. F. *Roadmaps for Clinical Practice: Case Studies in Disease Prevention and Health Promotion: Assessment and Management of Adult Obesity: A Primer for Physicians*. American Medical Association, Chicago, Ill., 2003. Available at www.amaassn.org/ama/pub/category/ 10931.html.

Laberge-Nadeau, C., G. Dionne, U. Maag, D. Desjardins, C. Vanasse, and J. Ekoe. Medical Conditions and the Severity of Commercial Motor Vehicle Drivers' Road Accidents. *Accident Analysis and Prevention*, Vol. 28, No. 1, 1996, pp. 43–51.

LaJambe, C. M., G. H. Kamimori, G. Belenky, and T. J. Balkin. Caffeine Effects on Recovery Sleep Following 27 Hours' Total Sleep Deprivation. *Aviation, Space, and Environmental Medicine*, Vol. 76, 2005.

Luepker, R. V., and M. L. Smith. Mortality in Unionized Truck Drivers. *Journal of Occupational Medicine*, Vol. 20, No. 10, 1978, pp. 677–682.

McArdle, W. D., F. I. Katch, and V. L. Katch. *Exercise Physiology: Energy, Nutrition, and Human Performance* (3rd ed.). Lea & Febiger, Philadelphia, Pa., 1991.

McCallum, M., T. Sandquist, M. Mitler, and G. P. Krueger. *Commercial Transportation Operator Fatigue Management Reference*. Research and Special Programs Administration, U.S. Department of Transportation, 2003. (Technical Report: OTA MP/ DTRS56-01-T-003, Battelle Transportation Research Center, Seattle, Wash., July 2003.)

McCart, A. T., J. W. Rohrbaugh, M. C. Hammer, and S. Z. Fuller. Factors Associated with Falling Asleep at the Wheel Among Long-Distance Truck Drivers. *Accident Analysis and Prevention*, Vol. 32, No. 4, 2000, pp. 493–504.

McGlothin Davis, Inc. *TCRP Report No. 77: Managing Transit's Workforce in the New Millennium*. Transportation Research Board, National Research Council, Washington, D.C., 2002.

McKnight, A. J., D. Shinar, and B. Hilburn. The Visual and Driving Performance of Monocular and Binocular Heavy-Duty Truck Drivers. *Accident Analysis and Prevention*, Vol. 23, No. 4, 1991, pp. 225–237.

McLellan, T. M., M. B. Ducharme, F. Canini, D. Moroz, D. G. Bell, J. V. Baranski, V. Gil, A. Buguet, and M. W. Radomski. Effect of Modafinil on Core Temperature During Sustained Wakefulness and Exercise in a Warm Environment. *Aviation, Space, and Environmental Medicine*, Vol. 73, No. 11, 2002, pp. 1079–1088.

Miyamoto, M., Y. Shirai, Y. Nakayama, Y. Gembun, and K. Kaneda. An Epidemiologic Study of Occupational Low Back Pain in Truck Drivers. *Journal of Nappon Medical School*, Vol. 66, No. 3, 2000, pp. 186–190.

Montplaisir, J., and R. Godbout. Restless Leg Syndrome and Periodic Movements During Sleep In *Principles and Practice of Sleep Medicine* (M. Kryger, T. Roth, and W. C. Dement, eds.). Saunders, Philadelphia, Pa., 1989, pp. 402–409.

Morin, C. M. *Insomnia: Psychological Assessment and Management*. Guilford Press, New York, 1993.

Moscovitch, A., D. Wartman, et al. *Fatigue Management Program for the Commercial Motor Vehicle Industry: An On-Going Field Study*. Canadian Sleep Institute, Calgary, Alberta, Canada, 2004.

Moskowitz, H., and C. J. Wilkinson. *Antihistamines and Driving-Related Behavior: A Review of the Evidence for Impairment*. DOT Technical Report No. HS-809-714. NHTSA, U.S. Department of Transportation, 2004.

Murphy, L. R. Job Dimensions Associated with Severe Disability Due to Cardiovascular Disease. *Journal of Clinical Epidemiology*, Vol. 44, No. 2, 1991, pp. 1255–166.

NTSB. *Safety Study: Fatigue, Alcohol, Other Drugs, and Medical Factors in Fatal-to-the-Driver Heavy Truck Crashes*, Vol. 1. NTSB Report No. NTSB/SS-90/01. NTSB, U.S. Department of Transportation, 1990.

Orris, P., S. Buchanan, A. Smiley, D. Davis, D. Dinges, and G. Bergoffen. *CTBSSP Synthesis of Safety Practice 9: Literature Review on Health and Fatigue Issues Associated with Commercial Motor Vehicle Driver Hours of Work*. Transportation Research Board of the National Academies, Washington, D.C., 2005.

Pack, A., D. F. Dinges, and G. Maislin. *A Study of Prevalence of Sleep Apnea Among Commercial Truck Drivers*. FMCSA Technical Report No. 02-030. Office of Research and Technology, FMCSA, U.S. Department of Transportation, 2002.

Paul, M. A., G. Gray, M. MacLellan, and R. A. Pigeau. Sleep-Inducing Pharmaceuticals: A Comparison of Melatonin, Zaleplon, Zopiclone, and Temazepam. *Aviation, Space, and Environmental Medicine*, Vol. 75, No. 6, 2004, pp. 412–519.

Pratt, K. L., R. H. Mattson, N. J. Wubers, and R. Williams. EEG Activation of Epileptics Following Sleep Deprivation: A Prospective Study of 114 Cases. *Electroencephalographic Clinical Neurophysiology*, Vol. 24, 1968, pp. 11–15.

Pratt, S. G. *Work-Related Roadway Crashes: Challenges and Opportunities for Prevention*. NIOSH Publication No. 2003-119. Department of Health and Human Services, NIOSH, Cincinnati, Ohio, 2003.

Rafnsson, V., and H. Gunnarsdottir. Mortality Among Professional Drivers. *Scandinavian Journal of Work and Environmental Health*, Vol. 17, No. 5, 1991, pp. 312–317.

Ramakers, J. G. Antidepressants and Driver Impairment: Empirical Evidence from a Standard On-the-Road Test. *Journal of Clinical Psychiatry*, Vol. 64, No. 1, 2003, pp. 20–29.

Reinberg, A. Strategy for Chronotherapy of Insulin-Dependent Diabetes Mellitus. Presented at Clinical Applications in Chronobiology Seminar, National Institutes of Health, June 20, 1989.

Reiter, R. J., and J. Robinson. *Melatonin: Your Body's Natural Wonder Drug*. Bantam Books, New York, 1995.

Roberts, S., and J. York. *Design, Development and Evaluation of Truck and Bus Driver Wellness Programs*. Final Report. Office of Research and Technology, FMCSA, U.S. Department of Transportation, 2000.

Robin, J., and S. Roberts. Truck Stop Fitness Facility Utilization Study. *Proc., Second International Large Truck and Bus Safety Symposium*, University of Tennessee Transportation Center, Knoxville, October 1999, pp. 189–198.

Robinson, C. F., and C. A. Burnett. Truck Drivers and Heart Disease in the United States, 1979–1990. *American Journal of Industrial Medicine*, Vol. 47, 2005, pp. 113–119.

Robinson, G. S., J. G. Casali, and S. E. Lee. *Role of Driver Hearing in Commercial Motor Vehicle Operation: An Evaluation of the FHWA Hearing Requirement*. Report DTFH61-95-C-00172 (NTIS No. PB98-114606). FHWA, U.S. Department of Transportation, 1997

Rogers, P. N., M. Ratz, and M. K. Janke. *Accident and Conviction Rates of Visually Impaired Heavy-Vehicle Operators: Final Report*. California Department of Motor Vehicles, Sacramento, 1987.

Rosa, R. R., and M. J. Colligan. *Plain Language About Shiftwork*. Public Health Service, U.S. Department of Health and Human Services, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, Cincinnati, Ohio, 1997.

Saltzman, G. M., and M. H. Belzer. The Case for Strengthened Motor Carrier Hours of Service Regulations. *Transportation Journal*, Vol. 41, No. 4, 2002, pp. 51–71.

Saltzman, G. M., and M. H. Belzer, eds.*Truck Driver Occupational Safety and Health: Conference Report and Selective Literature Review*. Wayne State University, Detroit, Mich., 2003.

Shiftwork. In *Occupational Medicine: State of the Art Reviews, Vol. 5, No. 2* (A. J. Scott, ed.). Hanley & Belfus, Inc., Philadelphia, Pa., 1990.

Scott, A. J. Shift Work and Health. *Primary Care*, Vol. 27, No. 4, 2000, pp. 1057–1078.

Sensi, S., F. Capani, M. Bertini, et al. Circadian Variation in Insulin Response to Tolbutamide and Related Hormonal Levels in Fasting Healthy Subjects. *International Journal of Chronobiology*, Vol. 3, 1976, pp.141–153.

Seshagiri, G. Occupational Noise Exposure of Operators of Heavy Trucks. *American Industrial Hygiene Association*, Vol. 59, No. 3, 1998, pp. 205–213.

Sharkey, K. M., L. F. Fogg, and C. I. Estman. Effects of Melatonin Administration on Daytime Sleep After Simulated Night Shift Work. *Journal of Sleep Research*, Vol. 10, 2001, pp. 181–192.

Solomon, A. J., J. T. Doucette, E. Garland, and T. McGinn. Healthcare and the Long Haul: Long-Distance Truck Drivers—A Medically Underserved Population. *American Journal of Industrial Medicine*, Vol. 46, 2004, pp. 463–471.

Staplin, L., K. Gish, and E. Wagner. MaryPODS Revisited: Updated Crash Analysis and Implications for Screening Program Implementation. *Journal of Safety Research*, Vol. 34, No. 4, 2003, pp. 389–397.

Staplin, L., and K. Lococo. *Model Driver Screening and Evaluation Program: Guidelines for Motor Vehicle Administrators*. NHTSA Report No. DOT HS 809-581. NHTSA, U.S. Department of Transportation, 2003.

Stoohs, R. A., C. Guilleminault, and W. C. Dement. Sleep Apnea and Hypertension in Commercial Truck Drivers. *Sleep*, Vol. 16, No. 8, 1993, pp. S11–S14.

Stoohs, R. A., L. A. Bingham, A. Itoli, C. Guilleminault, and W. C. Dement. Sleep and Sleep-Disordered Breathing in Commercial Long-Haul Truck Drivers. *Chest*, Vol. 107, 1995, pp. 1275–1282.

Stoohs, R. A., C. Guilleminault, A. Itoli, and W. C. Dement. Traffic Accidents in Long-Haul Truck Drivers: The Influence of Sleep-Disordered Breathing and Obesity. *Sleep*, Vol. 17, No. 7, 1994, pp. 619–623.

Stutts, J. C. *NCHRP Synthesis of Highway Practice 287: Sleep Deprivation Countermeasures for Motorist Safety*. TRB, National Research Council, Washington, D.C., 2000.

Sweeny, D. R. *Overcoming Insomnia: A Medical Program for Problem Sleepers*. G. P. Putnam's Sons, New York, 1989.

Tepas, D. I. Work Shift Usability Testing. In *The Occupational Ergonomics Handbook* (W. Karwowski and W. S. Marris, eds). CRC Press, Boca Raton, Fla., 1990, pp. 1741–1758.

Tepas, D. I., M. J. Paley, and S. M. Popkin. Work Schedules and Sustained Performance. In *Handbook of Human Factors and Ergonomics* (G. Salvendy, ed.), 2nd ed. Wiley & Sons, New York, N. Y., 1997, pp. 1021–1058.

Tharp, B. Epilepsy and Sleep. In *Sleeping and Waking Disorders: Indications and Techniques* (C. Gulleminault, ed.). Addison-Wesley, Menlo Park, Calif., 1982, pp. 373–381.

Truck Driver Occupational Safety and Health Conference Proceedings. University of Michigan Detroit, March 2005. Available at www.ilir.umich.edu/tibp/truckdriverosh/.

U.S. Department of Labor Bureau of Labor Statistics. *Census of Fatal Occupational Injuries*. Bureau of Labor Statistics, U.S. Department of Labor, 2001, Table A-5. Available at http://bls.gov/iif/oshwc/cfoi/cftb0149.pdf.

U.S. Department of Labor Bureau of Labor Statistics. *Case and Demographic Characteristics for Work-Related Injuries and Illnesses Involving Days Away from Work*. Bureau of Labor Statistics, U.S. Department of Labor, 2001, Table 2. Available at www.bls.gov.iif/oshwc/osh/case/ostb1145.pdf.

U.S. Department of Labor Bureau of Labor Statistics. *National Occupational Employment and Wage Estimates, Transportation, and Material Moving Occupations*. Bureau of Labor Statistics, U.S. Department of Labor, 2001. Available at www.bls.gov/oes/2001/oes_53Tr.htm.

U.S. Department of Labor Bureau of Labor Statistics. *Occupations with the Highest Rates of Fatal Injuries*. Bureau of Labor Statistics, U.S. Department of Labor, 1993. Available at www.osha.gov/oshinfo/priorities/appendixA/ table6.html.

U.S. Department of Labor Bureau of Labor Statistics. *Occupations with the Most Injuries and Illnesses with Days Away from Work, 2002*. Bureau of Labor Statistics, U.S. Department of Labor, 2002. Available at www.bls.gov/opub/cwc/ sh20040525ch0l.htm.

U.S. Food and Drug Administration. *Laser Eye Surgery and Learning about LASIK*. USDA Center for Devices and Radiological Health, U.S. Food and Drug Administration, 2006. Available at www.fda.gov.

Vanderveen, J. E. *Caffeine for the Sustainment of Mental Task Performance: Formulations for Military Operations*. Institute of Medicine Committee on Military Nutrition Research Food and Nutrition Board, National Academy Press, Washington, D.C., 2001.

Wesensten, N. J., G. Belenky, D. R. Thorne, M. A. Kautz, and T. J. Balkin. Modafinal vs. Caffeine: Effects on Fatigue During Sleep Deprivation. *Aviation, Space, and Environmental Medicine*, Vol. 75, 2004, pp. 6520–6525.

Whitehouse, F., et al. *Conference on Diabetic Disorders and Commercial Drivers*. FHWA Report No. MC-88-041. Federal Highway Administration, U.S. Department of Transportation, 1988.

Wierwille, W. W. Historical Perspective on Sow Eyelid Closure: Whence PERCLOS? In *Ocular Measures of Driver Alertness Technical Proceedings* (R. J. Carroll, ed.). FHWA Technical Report No. MC-99-136. Federal Highway Administration, U.S. Department of Transportation, 1999, pp. 31–53.

Wierwille, W. W. Desired Attributes of Drowsy Driver Monitoring and Candidate Technologies for Implementation. In *Ocular Measures of Driver Alertness Technical Proceedings* (R. J. Carroll, ed.). FHWA Technical Report No. MC-99-136. Federal Highway Administration, U.S. Department of Transportation, 1999, pp. 130–143.

Wood, J. M., and R. Troutbeck. Effect of Restriction of the Binocular Visual Field on Driving Performance. *Ophthalmic and Physiological Optics*, Vol. 12, 1992, pp. 291–298.

Wood, J. M., and R. Troutbeck. Effect of Visual Impairment on Driving. *Human Factors*, Vol. 36, 1994, pp. 476–487.

Wylie, C. D. Sleep, Science, and Policy Change (editorial). *New England Journal of Medicine*, Vol. 352, No. 2, 2005, pp. 196–197.

Young, T., M. Palta, J. Dempsey, J. Skatrud, S. Weber, and S. Badr. The Occurrence of Sleep-Disordered Breathing Among Middle-Aged Adults. *New England Journal of Medicine*, Vol. 328, No. 17, 1993, pp. 1230–1235.

Commercial Driver Human Factors

WILLIAM C. ROGERS
RONALD R. KNIPLING

Crash causation statistics consistently have shown that driver errors—mistakes and misbehaviors—are the principal contributing factors to traffic crashes. The classic Indiana Tri-Level Study (Treat et al., 1979) identified principal and contributing causal factors for 420 light-vehicle crashes on the basis of in-depth, multidisciplinary investigations. Percentages for the three major crash causal categories were as follows: human (93%), environmental (34%), and vehicular (13%). Within the human category, major subcategories included recognition failures (failure to perceive crash threat), decision errors (including voluntary precrash misbehaviors such as speeding), performance errors (failure to safely execute a driving maneuver), and critical non-performance, which included asleep-at-the-wheel and blackouts due to medical factors.

Both unintentional mistakes and voluntary precrash misbehaviors contribute to crash causation for both commercial and noncommercial drivers. Commercial drivers, however, are less likely than noncommercial drivers to engage in egregious illegal or risky behaviors such as driving without a license, alcohol use, or reckless speeding (Knipling et al., 2004a). For example, in 2002 only 2% of large truck drivers in fatal crashes had tested BAC levels above 0.08%, versus about 25% of drivers of passenger vehicles (NHTSA, 2003).

The FMCSA–NHTSA LTCCS (FMCSA. 2006) has identified a profile of contributing factors for crashes involving large trucks. Of serious large-truck crashes in the LTCCS (including both single- and multivehicle crashes), 48% had a "critical reason" assigned to the driver of the large truck. Environmental and vehicular critical reasons relevant to the truck accounted for 1% and 6% of the crashes, respectively. The critical reason was "not coded to truck" (e.g., it was coded to the other involved vehicle or driver) 45% of the time. Of the 48% of LTCCS crashes with critical reasons assigned to large-truck drivers, the error type classifications were as follows: recognition errors (16%), decision errors (21%), performance errors (5%), and driver nonperformance (6%). A principal goal of human factors studies of commercial drivers and their crashes is to understand the types of human errors resulting in crashes and the human risk factors that make these errors and crash outcomes more likely.

Of two-vehicle crashes involving one truck and one passenger vehicle in the LTCCS data set, 44% had a critical reason assigned to the truck or truck driver, while 56% had a critical reason assigned to the other vehicle or driver. Of course, the vast majority of these critical reasons were driver related rather than related to the vehicles or the roadway environment. An important caveat relating to the LTCCS data and findings is that critical reason is not necessarily synonymous with fault, cause, or legal culpability. The critical reason is the immediate cause of the critical event making the crash inevitable (Blower and Campbell, 2005). Typically driver mistake or misbehavior triggers the crash sequence but should not be regarded as the root cause of the crash.

Previous studies of driver factors identified in fatal crash investigations (Blower, 1998) and instrumented vehicle studies (Hanowski et al., 2000) of critical incidents and near-crashes have also found that a majority of large truck–light vehicle crashes and incidents can be attributed principally to driving mistakes or misbehaviors of light vehicle drivers. In contrast, Council et al. (2003) identified principal fault in 1994–1997 North Carolina PARs for truck–car crashes of all severity levels. In this sample, truck drivers were assigned fault in more of the crashes (48%) than were car drivers (40%).

As noted in the introduction, there is evidence that, in general, truck–car crashes are precipitated by the same driver errors that precipitate crashes in general. Kostyniuk, Streff, and Zakrajsek (2002) analyzed 1995–1998 fatal crashes and found that, in general, the driving actions leading to fatal car–truck crashes are the same that lead to fatal car–car crashes. Common driver errors resulting in both types of fatal crashes included failing to keep in lane, failing to yield right-of-way, driving too fast for conditions, disobeying traffic controls and laws, and inattention. These driver mistakes and misbehaviors accounted for about two-thirds of both car–truck and car–car fatal crashes.

With the exception of truck driver fatigue and loss of alertness and, to a lesser extent, driver interaction with ITS, the majority of research over the past two decades on individual human factors influencing driving behavior has centered on the light-vehicle driver or the overall population of drivers (Lancaster and Ward, 2002). In their review of the international literature on work-related road safety, Lancaster and Ward identified 16 individual differences (human factors) that contributed to driving behavior and crash involvement:

- Age,
- Gender,
- Education,
- Personality,
- Aggression,
- Thoroughness in decision making,
- Driving confidence,
- Attitudes,
- Risk perception,
- Social deviance,
- Experience and previous motor vehicle accidents,
- Stress,
- Life events and factors,
- Fatigue,
- Physiology, and
- Ethnicity.

This chapter addresses several major human factors topics, including driver functional capabilities, driver age and demographic trends, commercial driver training, driver fatigue and drowsiness, and macroergonomics and safety motivation.

DRIVER FUNCTIONAL CAPABILITIES

A commercial driver's ability to see, recognize, decide, and act are critical to most driving tasks. Llaneras et al. (1995), in a study of older truck drivers, developed a useful typology of 15 driving-related perceptual, cognitive, and psychomotor abilities. These are listed and defined in Table 1.

TABLE 1 Major Driver Functional Abilities (from Llaneras et al., 1995)

Ability	**Definition**
Perceptual (Visual)	
Static visual acuity	The ability to resolve the details of a stationary object
Dynamic visual acuity	The ability to resolve details of a moving object
Contrast sensitivity	The ability to detect targets of varying contrast
Useful field of view	The area of the visual field that is useful for acquiring information during a brief glance
Field independence	The ability to perceive relevant targets embedded within a complex scene
Depth perception	The ability to judge distances and change in distance
Cognitive	
Decision making	The ability to determine when a situation requires action, select among alternative courses of action, and execute the appropriate response
Selective attention	The ability to select one stimulus source from among others, and to filter out potential distracters
Attention sharing	The ability to shift attention between multiple sources of information
Information processing	The ability to search for and extract information and perform mental operations
Psychomotor	
Reaction time	The ability to respond quickly to a signal
Multilimb coordination	The ability to coordinate multiple limb movements
Control precision	The ability to position controls accurately, quickly, and repeatedly
Tracking	The ability to follow a path or pursue a moving target
Range of motion	Limb and joint movement and flexibility as measured by degrees of angles of movements

The most important perceptual abilities associated with driving are visual. As noted previously, recognition failures are a major category of human error associated with crashes. Cognitive abilities are related to driving decisions and also to maintaining attention to the driving task. A variety of psychomotor abilities are obviously required to drive a vehicle. While the physical demands associated with driving an automobile have been reduced by the introduction of power steering, power brakes, and automatic transmissions, operating CMVs tend to be more physically demanding. For example, the vast majority of CMVs are still equipped with manual transmissions, often with 16 speeds, that require frequent shifting. (Automatic transmissions are becoming more common but are still are in a minority of new tractors. Most of these transmissions must be shifted but do not require operation of a clutch pedal.).

The Llaneras et al. study found that driver performance on most of the ability tests (administered in a laboratory) was predictive of driving performance on a simulator, and also that performance on these tests tended to decrease with age. However, age itself was not predictive of driving performance. Specific abilities with the strongest relations to driving performance on a simulator included driver range of motion, attention sharing, depth perception, useful field of view, and field independence/dependence.

YOUNG COMMERCIAL DRIVERS

Among the general population of drivers, age has a strong relationship to crash involvement (NHTSA 2000). Teenage drivers have crash rates that are several times those of the middle-aged driver population. Crash rates (per mile traveled) are highest during the first years of driving but steadily decline during the late teens and throughout the 20s. They reach their lowest levels in the 40s and 50s, remain relatively low in the 60s, and then begin to rise in the 70s. It's not until the mid-80s that older drivers have crash rates similar to those of new teenaged drivers.

Blower (1996) conducted a statistical analysis of young commercial driver crash involvements and violations using Michigan and North Carolina data. Young drivers (aged 18 to 21) had moving violation rates that were almost twice that of middle-aged drivers (aged 30 to 49) in the study. Crash involvement rates per mile traveled could not be calculated because of lack of exposure data. However, when crashes occurred, young commercial drivers were about 50% more likely than middle-aged drivers to be charged with a violation relating to the crash. In large truck–light vehicle crashes, young truck drivers were more likely than the light vehicle driver to be charged with a crash-related hazardous action or violation. The opposite is true for large truck–light vehicle crashes in general.

In an instrumented vehicle study of local and short-haul commercial drivers, Hanowski et al. (2000) found that driver age was the factor most predictive of the occurrence of safety-significant errors by the commercial driver. Driver age was a stronger predictor than several fatigue-related measures, including prior night's sleep, current drowsiness rating, and physical labor performed during the work shift.

Because of the well-documented safety risks associated with younger drivers, most motor carriers avoid hiring commercial drivers younger than 25. The majority of high-safety fleets consider age to be an important selection factor in hiring drivers. In a survey of carrier safety managers by Knipling et al. (2004b), the characteristic young driver (younger than 25) was rated as having the sixth highest association with risk of 16 factors in the survey.

OLDER COMMERCIAL DRIVERS

Research results and crash data do not appear to indicate that older commercial drivers represent a greater crash risk than middle-aged commercial drivers. First, most older CMV drivers are in the "young old" range, e.g., late 50s and 60s. Many such CMV drivers have decades of experience and are among the most valued drivers in their fleets. In the above-mentioned survey of carrier safety managers, older driver (60 or older) was rated 12th of 16 factors in strength of association with crash risk.

The primary motivation for the Llaneras et al. (1995) study discussed earlier in this chapter was to determine whether older commercial drivers should be a particular concern for the commercial transport industry. The study tested several age groups of commercial drivers using various laboratory tests of functional capabilities as well as driving performance on a simulator. The study found that certain aspects of perceptual, cognitive, and psychomotor performance abilities did tend to deteriorate with increasing age and did correlate with driving performance on a simulator. However, there were wide variations among individuals within an age group. Useful field of view, control precision, tracking, decision making, and information processing were among the functional abilities showing the greatest declines with age. Dynamic acuity and field independence/dependence degraded earliest, while multilimb coordination and simple reaction time were most resistant to age effects.

The researchers also evaluated four interventions: an auditory navigation system, an automatic transmission, an auditory brake temperature warning system, and visual search and scanning training. Results indicated that all four interventions improved driving performance on the simulator. The researchers came to the following conclusions:

- Significant decrements of perceptual, cognitive, and psychomotor abilities occur with advancing age. Age appears to act as a moderator variable that influences driving performance indirectly through intervening variables such as perceptual, cognitive, and psychomotor abilities.
- One of the strongest and most pervasive relationships with driving performance was range of motion as measured by torso flexibility. It was the only significant predictor of vehicle collisions. Physical therapy for improving range of motion may be an effective safety intervention for drivers 55 years and older.
- Compensatory and training-oriented interventions can be an effective and efficient means of curtailing age-related degradation of relevant driving abilities.
- Driver screening systems should incorporate measures of functional abilities associated with driving regardless of driver age.

Although physical decrements are apparent in older commercial drivers in comparison to their younger peers, these decrements are not apparent in crash rates. It appears that the experience and engrained safety habits of older CMV drivers compensate for most declines in sensory-motor or cognitive abilities.

DEMOGRAPHIC TRENDS AND THE DRIVER SHORTAGE

By 2008, 40% of the labor force will be 45 years of age or older; conversely, only 44% will be workers aged 25 to 44 years (Dohm, 2000). After 2008, the retirement rate will increase dramatically, and by 2018 almost all of the baby boomers will be of retirement age. For several reasons, this will have a significant effect on the truck and bus industries.

First, some segments of the CMV industry (e.g., some motor coach, private, and less-than-truckload operations) have more older workers because they are offer more favorable working conditions (in terms of schedule and general operational stability and predictability), are often unionized, reward seniority, pay higher wages, and give better benefits. For these reasons, carrier driver retention is better, and, therefore, drivers tend to be older. For instance, of the estimated 474,000 bus drivers in 1998, 54% were 45 years of age and older (Dohm, 2000). Of course, this means that driver replacement needs in the next decade will be greatest in these segments. Dohm (2000) found that a total of 22.2 million will be retiring. The second highest demand, trailing only secretaries, will be to replace 425,000 drivers of heavy trucks (Dohm, 2000).

Current economic and labor projections for the next decade indicate that economic growth and resulting transportation requirements are likely to exceed growth significantly in the driver labor pool, resulting in a worsening driver shortage (Guido, 2005).

Furthermore, in addition to competing with other high-demand occupations for new workers, truck and bus driver jobs are labor intensive, have a minimum age requirement of 21 years (and many fleets do not hire drivers younger than 23, 24, or 25), and require a steep learning curve in order to reach safe performance levels. All these factors may reduce the appeal of these jobs to younger workers and exacerbate the commercial driver shortage.

White male truck drivers have traditionally dominated the truckload segment of the industry. In 2003, only 5% of all truck drivers were females (ATA, 2004). Women are potentially the greatest source of new drivers—if the trucking industry can improve its recruitment of women and overcome the reluctance of women to enter the occupation in the first place. That reluctance is significant. The Gallup Organization (1997) randomly surveyed 1,000 adults about public perceptions of truck driving. On one question, "the industry needs to recruit more women drivers," the group who least agreed with that statement were women (59%). In contrast, the study found that women who were long-tenured truck drivers were much more likely than males to see trucking as a good occupational choice. In any event, there is clearly a need to broaden the demographic profile of North American commercial drivers to include more women and minorities (Guido, 2005).

DRIVER TRAINING

The demand for qualified truck drivers, new operational technologies (e.g., onboard computers, diagnostic systems, GPS), and the trucking industry's poor retention rate for drivers in some industry segments place an increasing importance on the quality and student output of commercial driver training programs. Improved commercial driver training was the No. 1 recommendation from the April 2002 International Truck and Bus Research and Policy Symposium (Zacharia and Richards, 2002). The specific recommendation was that "the Federal Government should mandate and develop standardized CMV driver training that shall include entry-level, sustained (in-service), and remedial training to teach the proper skills, performance, and behaviors necessary to be a safe CMV driver." Staplin et al. (2004) reviewed CMV driver training strategies and curricula and identified various training tools and techniques holding potential to improve driver performance and safety.

FHWA OMC published a comprehensive model entry-level training curriculum in 1985 (FHWA, 1985), but it was never implemented as mandatory training standards for entry-level CMV drivers. The Professional Truck Driver Institute (1999) currently promulgates a similar model curriculum for voluntary adoption by schools. FMCSA recently published a final rule establishing standards for mandatory training requirements on four specific topics, including driver medical qualification and drug and alcohol testing, driver HOS rules, driver wellness, and whistleblower protection [Minimum Training Requirements for Entry-Level Commercial Motor Vehicle Operators; Final rule; RIN 2126-AA09; FMCSA-1997-2199; (69 FR 29384)].

Generically, training is defined by Swezey and Andrews (2001) as "the systematic application of scientific learning principles to produce instruction that will change behavior." Types of training relevant to commercial drivers include entry-level training, in-service "finishing," other fleet training for new hires, refresher training (e.g., for all drivers in a fleet), and remedial training (i.e., for problem drivers). Driving schools are the primary institutions where novice drivers receive their initial driver training and education. A 1995 evaluation (Dueker, 1995) of entry-level training addressed three sectors of CMV operations: heavy trucks, motor coaches, and school buses. The study concluded that none of the three sectors were providing adequate entry-level training for their commercial drivers. Among heavy-truck drivers, for example, about 62% were trained, but only 50% of these training programs were judged adequate. Thus, about 31% (62% x 50%) of drivers were deemed adequately trained. Corresponding percentages of drivers adequately trained for driving motor coaches and school buses were 18% and 34%, respectively. Some entry-level CMV driving schools have a reputation of being CDL mills that teach sufficient knowledge and skills to pass the CDL test but do not prepare drivers adequately for the rigors of actual CMV operational driving. This has prompted fleets to rely heavily on their own in-house training programs for new hires. Of award-winning fleets surveyed by ATA (ATA Foundation, 1999) in *SafeReturns*, 85% maintained their own in-house driver training programs. Techniques employed to train drivers include classroom and behind-the-wheel (BTW) training. BTW training may be on the open road or on a practice range. PC-based training programs are also beginning to penetrate the commercial driver training community. New-generation PC-based training simulators are taking advantage of faster microprocessors and specialty graphics hardware to provide a more realistic driver-in-the-loop experience for the student.

There have been few controlled studies that have assessed the efficacy of training programs for CMV drivers. However, Horn and Tardif (1999) reported on a large U.S. trucking fleet that instituted a training program that resulted in a 14% reduction in crashes and a retraining program with 1,300 drivers at a German food distribution company that led to a greater-than-50% reduction in the company driver crash rate. Moreover, Cleaves (1997) reported a reduction of almost 50% in the number of crashes after the implementation of a driver training program at a large carrier fleet.

Western Europe generally places greater emphasis on commercial driver training than does the United States (Hartman et al., 2000). Europe has training standards for new commercial drivers and requires comprehensive vocational training. In contract, the United States does not require any amount of training but rather requires that new drivers pass CDL knowledge and skill testing. Alberta has an initiative to formally recognize driver completion of more comprehensive training. A special professional designation will be given for driver completion of a 1-year apprenticeship program that includes 6 weeks of classroom training, 6 weeks on-board training, and the rest of the year under professional mentoring. The program will include non-driving-specific topics such as cargo securement, fatigue management, and international custom regulations.

Driving simulators may hold promise to enhance commercial driver training and testing (Robin et al., 2005). Over the past decade or more, high-fidelity, "full mission" truck driving simulators have become commercially available at a typical price of several hundred thousand dollars. At this writing, however, only a handful of U.S. truck driving schools utilize such simulators. Part-task trainers, such as transmission (gear-shifting) trainers, are less expensive and more common, though apparently not yet in widespread use.

There are many major advantages to the use of simulation in training. They include

- Safety: simulators allow risk-free practice of both basic and emergency maneuvers.
- Scenario versatility: scenarios can be developed to present dangerous or inaccessible roadway environments, such as icy roads, fog, mountain grades, and narrow city streets.
- Standardization: scenarios can be developed to support specific instructional objectives, and organized to ensure that all students are exposed to all learning activities.

- Repeatability: student performance can be replayed to allow both students and instructors to analyze safety-related skills and behaviors, and also replayed until students demonstrate skill mastery.
- Improved perspectives: in many simulators, a flip of a switch can provide both the student and the instructor with an overhead view of the vehicle and the roadway, a feature that is particularly helpful in training vehicle positioning for turns, parallel parking, and other tight maneuvers.
- Finer performance measurement: simulators can record student performance in more precise and quantitative ways than can instructors or other human observers. For example, continuous quantitative measures can be provided for lane keeping and headway maintenance.
- Efficiency: if a school is equipped with multiple simulators or other student workstations, a single instructor can monitor the skill learning and performance of several students simultaneously.

Truck driving simulators are already in use in France, Sweden, and other European countries (Hartman et al., 2000) but are used in only a few schools in the United States and Canada. FMCSA has an active research program under way to assess the state of truck driving simulation and determine, through a formal validation study, the optimal uses of simulation to enhance the training of both basic and specialized skills (e.g., emergency maneuvering) (Robin et al., 2005; Emery et al., 1999). The project is called the Simulation Validation or "SimVal" project. The most fundamental question to be asked by the SimVal study is whether simulation enhances the effectiveness and efficiency of entry-level driver training. In addition to simulation and BTW experimental conditions, the study will test students who have received little or no formal commercial driving training and also those who have received abbreviated, CDL-focused training. This will permit evaluation of the effectiveness of CMV driver training in general, as well as the evaluation of simulation training vis-à-vis conventional BTW training. In addition, the program will assess the training benefits of advanced simulator capabilities such as the simulation of emergency maneuvers and dangerous roadway conditions. Figure 1 shows the FAAC, Inc., truck driving simulator being used in the SimVal study.

Another program supporting the use of simulation training for commercial drivers is under way in the United Kingdom at the Transport Research Laboratory (TRL). The program is called TruckSim, and its website is www.trucksim.co.uk.

Much driver training occurs within carrier fleets (e.g., "finishing," refresher, and remedial training) rather than schools. The chapter on carrier safety management in this circular discusses in-fleet training as a major safety function of fleet management.

DRIVER FATIGUE AND LOSS OF ALERTNESS

No area of commercial driving has received more study and notoriety over the past decade than driver fatigue (Wylie et al., 1996; Knipling et al., 2002). There are several operational risk factors that increase the likelihood that commercial operators will work in a state of fatigue:

- Lack of sleep in principal sleep periods, especially if recurring over successive days;
- Extended work or commuting periods;

FIGURE 1 "Full mission" truck driver training simulator being employed in the SimVal study.

- Split-shift work schedules (unless there is an opportunity for napping during off-duty period);
- Work–sleep periods conflicting with circadian rhythm;
- Changing or rotating work schedules;
- Unpredictable work schedules;
- Lack of rest or nap periods during work;
- Sleep disruption;
- Inadequate exercise opportunities;
- Poor diet; and
- Environmental stressors (e.g., heat, cold, lack of ventilation).

Fatigue plays a major role in truck driving safety. For example, McCartt et al. (2000) conducted interviews with 593 long-distance truck drivers randomly selected at public and private rest areas and inspection stations. They found that 47% of the respondents reported having fallen asleep at the wheel of a large truck and that 25% had done so within the past year. Factors most associated with falling asleep included more arduous work schedules, more hours of work and fewer hours off-duty, and poorer sleep while on the road.

A 1990 crash investigation study by NTSB found that fatigue was the greatest single factor associated with crashes fatal to the truck driver. In general, two broad definitions of fatigue are used: the subjective feeling all people experience when they are tired and performance deficits such as decreases in attention or timing. Insufficient sleep is the main cause of fatigue, although in the case of commercial driving, time-of-day and individual differences can also play a significant role (Wylie et al., 1996).

The quantification of the role of truck driver fatigue in truck crashes is problematic because of differences among various crash samples and investigation methodologies used to compile crash statistics. Percentages in the literature range from a low of 0.36% for police-reported data on all crash truck samples (Knipling and Shelton, 1999) to 31% for in-depth studies of fatal-to-the-driver large truck crashes (NTSB, 1990). Fatigue statistics relating to specific subpopulations of truck crashes ordinarily cannot be generalized to larger populations. For example, fatal-to-the-driver truck crashes, though obviously important in their own right, represented only one in every 676 large truck crashes for the 6-year period 1992–1997 and had a police-reported fatigue percentage that was 29 times that of the overall population of large-truck crashes (Knipling and Shelton, 1999). There are at least two sources of underestimation in police reports of fatigue involvement in crashes. First, police accident investigations tend to be relatively superficial. Comparisons of police-reported in-depth investigations of the same crash samples have shown that in-depth investigations cite fatigue about two to three times more frequently (Knipling and Shelton, 1999). Second, and more profound, crash investigations in general are not likely to capture the contributing role that fatigue may play in "awake" driver errors. In an instrumented vehicle study of local and short-haul driving, 20% of the driving errors committed by drivers were associated with elevated levels of PERCLOS, an eyelid droop measure of drowsiness (Hanowski et al., 2000). In a more recent naturalistic driving analysis of 661 long-haul truck driver at-fault traffic incidents, nearly 13% of incidents occurred during periods of moderate-to-high driver fatigue, although fatigue was identified as the critical reason in fewer than 2% of the incidents (Olson et al., 2005).

LTCCS is a new source of in-depth investigative data on large truck crashes. In LTCCS, truck driver critical nonperformance (which includes asleep-at-the-wheel and blackout due to illness) was designated the critical reason in 6.3% of large-truck crashes (FMCSA, 2006). Despite its sophistication as a crash investigation study, LTCCS suffers from the inherent limitations of the crash investigation methodology in identifying subtle contributing factors such as drowsiness. Drivers themselves may not be aware of the role that loss of alertness played in their crash, and even if they are, the fact may not emerge in the investigation.

The HOS rule that took effect in the United States on January 4, 2004, replaced regulations that had been in effect since 1939. Among the major changes were an increase in the daily off-duty requirement (from 8 to 10 h), an increase in the maximum hours of driving before going off-duty (from 10 to 11 h) hours, and the institution of a 34-h restart provision whereby weekly cumulative hours can be reset to zero. Various fatigue and scheduling issues were studied in support of the rulemaking, including the U.S. DOT–Transport Canada–sponsored Driver Fatigue and Alertness Study (DFAS), the largest over-the-road fatigue study ever conducted (Wiley et al., 1996). At this writing, Canada has announced new rules (available at http://canadagazette.gc.ca/partII/2005/20051116/html/sor313-e.html) that will be fully implemented by 2007.

DFAS (Wiley et al., 1996) monitored the performance and psychophysiology of 80 commercial drivers working four different schedules during a week of real operational driving. One major finding of the study was that the 80 drivers averaged only about 5 h of sleep per night, an amount that sleep deprivation studies (e.g., Balkin et al., 2000) have shown to be associated with increasingly degraded alertness performance over successive days. The increase in the daily minimum off-duty period from 8 to 10 h was motivated by the recognized need for increased daily sleep in the principal sleep period. Circadian (time-of-day) effects were pronounced; the late night–early morning hours (10 p.m. to 6 a.m.) were associated with an eightfold risk of drowsiness. Large-truck fatigue crashes also peak during the overnight hours, although there is evidence that the overall large-truck fatal crash rate (per mile traveled) is roughly constant over the 24-h day, most likely because of other risk factors besides fatigue (e.g., the actions of other motorists in traffic) that are greater during daytime (Hendrix, 2002). Time-on-task effects on alertness were not strong in the DFAS, a finding that may have been influential in FMCSA's decision to lengthen maximum daily driving hours from 10 to 11 h.

Other studies (e.g., Lin, Jovanis, and Yang, 1994; Park et al., 2005) have shown significant safety effects time-on-task effects, however. In the Park et al. study, 16 million miles of driver log and crash data from a national less-than-truckload carrier (data collected during 1983–1984) were analyzed to quantify risks associated with various times of the day, time-on-task (hours driving), and schedule regularity. Night and early morning driving were associated with a 20% to 70% increase in crash risk compared with daytime driving. Irregular schedules with primarily night–early morning driving were associated with a 30% to 80% increase. Compared with the first hour of driving, there was a significant increase in crash risk during Hours 2 to 4, and a further, greater increase during Hours 5 to 10. The crash risk difference between the 10th hour of driving and the first hour of driving in the study was more than 80%.

In the DFAS, there was little correlation between driver self-ratings of alertness and concurrent objective performance and psychophysiologic measures. Other studies have shown that many drivers are poor in predicting the likelihood of imminent involuntary sleep (Itoi et al., 1993; Dinges, 2005). This points to the need and potential value of monitoring driver alertness using objective measures (if validated) and providing informational feedback to drivers about their alertness levels. Indeed, technologies that accurately monitor driver alertness have the potential to revolutionize driver fatigue management by providing continuous feedback to drivers on their alertness levels and performance. Two such sensor technologies are PERCLOS (eyelid droop) monitoring and lane position monitoring (e.g., lane weaving as measured by standard deviation of lane position). Both of these measures have been well validated as continuous measures of alertness and related performance (Dinges et al., 1998; Wierwille et al., 1994). Another technology that might help people to manage their sleep and wake schedules better to promote alertness and reduce drowsiness is the wrist-worn actigraph "sleep watch. There are two general requirements that must be met for fatigue management technologies to have genuine value. First, they must be shown to be based on valid, scientifically sound measures. Second, they must provide informational feedback to users in a manner that not only reduces the immediate crash threat but also motivates them to get more and better sleep. It's not likely that the in-vehicle use of alerting stimuli can sustain alertness (Dinges et al., 1998), so the primary goal of alertness monitoring must be to motivate drivers to get more sleep, both during principal sleep periods and naps. A more detailed list of scientific, engineering, practical, legal, and policy requirements is provided in Table 2 (Dinges, 1997).

One international review of fatigue technologies (Hartley et al., 2000) concluded that substantial further development is needed. The lack of dramatic technological progress in recent years does not, however, diminish the validity of proven fatigue measures (e.g., PERCLOS and lane keeping) or the potential benefits to be gained from successful technologies.

Brewster et al. (2005) reported the results of a pilot test of several fatigue management technologies, including a PERCLOS-based alertness monitor, lane position monitor and departure warning, and wrist-worn actigraphs. The objectives of the study were to assess

TABLE 2 Scientific, Practical, and Legal Criteria and Questions Regarding the Development and Use of Technologies for Monitoring Operator Vigilance or Impairment (Dinges, 1997)

Criteria	Question
Scientific/Engineering	
Validity	Does it measure what it purports to measure, both operationally (e.g., eye blinks) and conceptually (e.g., impairment)?
Reliability	Does it measure the same thing consistently?
Generalizability	Does it measure the same event (operationally and conceptually) in everyone?
Sensitivity	What proportion of the persons (or times within a given person) does it detect when reduced vigilance is actually present? (Does it miss some hypovigilance or some hypovigilant persons?)
Specificity	What proportion of the persons (or times within a given person) does it correctly identify safe vigilance when it is actually present? (How often does it false alarm?)
Practical/Implementation	
Ease of Use	Can nearly everyone use it correctly?
Acceptance	Will the target population use the technology?
Unobtrusiveness	Is the technology “transparent” or convenient for the user?
Robustness	Can the technology withstand heavy use and abuse?
Economical	Is the technology cost-effective?
Implementation	Operationally how is the technology to be used? (For example, does it only detect reduced vigilance conditions? Does it also alert the operator? If it alerts the operator, what is the nature of the alert? Does it trigger a broader countermeasure response?)
Legal/Policy	
Purpose	What is the goal of implementing the technology?
Privacy	Is use of the technology mandatory? (Who mandates and for what purpose?)
Enforcement	Is the technology to be used for enforcement, compliance, or advancement or demotion? If so, how is this accomplished?
Misuse potential	Can use of the technology lead to misuse (*a*) by the person being monitored (e.g., continuing to operate while impaired) and (*b*) by the mandating entity (e.g., requiring an operation to continue when impairment is present)?
Liability	Who is liable if the technology fails to detect impairment or if it is misused in association with an adverse event?

potential driver acceptance of these technologies and to determine whether feedback from them would motivate them to increase their sleep time and improve their alertness in the vehicle. Each driver experienced 2 weeks of baseline nonfeedback driving followed by 2 weeks of receiving feedback from the devices. There were positive effects of alertness and performance feedback on driver sleep duration and in-vehicle alertness, although subjective driver sleepiness was greater in the feedback condition. In addition, driver performance on the Psychomotor Vigilance Test (conducted during driving runs but with the vehicle stopped) showed reduced alertness performance during the feedback period. This suggested a possible alertness “cost” due to driver compensatory efforts to stay alert during feedback. Drivers indicated a strong preference for performance-related devices such as the lane tracker compared with psychophysiological devices (the PERCLOS monitor and the actigraph). Of course, these stated preferences could have been related to specific features of the devices tested as opposed to their fundamental modes of operation.

Another major finding of the DFAS was the pronounced individual difference in fatigue incident among the 80 drivers. In the study, 14% of the driver subjects accounted for 54% of observed drowsiness episodes, while 34% of the driver subjects had no observed drowsiness episodes. Figure 2 shows a frequency distribution of driver drowsiness episodes in the DFAS illustrating the wide variation in drowsiness frequency.

Similarly, in an instrumented vehicle study of local–short haul driver fatigue (Hanowski et al. 2000), four high-fatigue drivers (of 42 total) accounted for 7% of the hours driven but 39% of all drowsiness episodes. At the other extreme, there were 16 drivers who were never observed to be drowsy. Knipling (2005) has reviewed instrumented vehicle and other types of data from several studies and found similar disproportionate distributions of fatigue risk in all studies reviewed.

A key question is whether level of susceptibility to fatigue is a variable human state reflective of situational factors or whether it is a relatively intractable, enduring human trait. Support for the "trait" concept is provided by two studies showing that the alertness and performance effects of sleep deprivation are highly variable across individuals but quite stable and repeatable within individuals (Dinges et al., 1998; Van Dongen et al., 2004). For example, Figure 3 below shows the time course of deterioration in psychomotor vigilance task (PVT) performance (measured as lapses) for a single subject sleep-deprived for 40 h at two different times about 6 months apart.

Alerting stimuli provided during the second deprivation had little effect on alertness and the similarities are striking between the two deterioration time courses for this alertness measure.

If the trait interpretation has substantial truth, significant benefits would accrue from developing means to identify high- and low-susceptible individuals before they are placed in safety-critical jobs such as commercial driving. The existence of strong individual differences in fatigue susceptibility challenges the concept of invariant prescriptive HOS. If scientific knowledge and technology enabled it, fatigue regulations could be performance-based rather

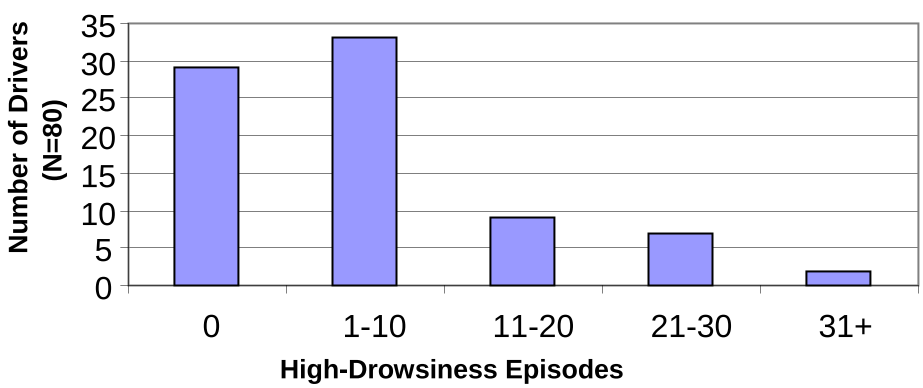

FIGURE 2 Frequency distribution of long-haul truck driver high-drowsiness episodes among 80 drivers of the DFAS (Knipling et al., 2004b, derived from Wylie et al., 1996).

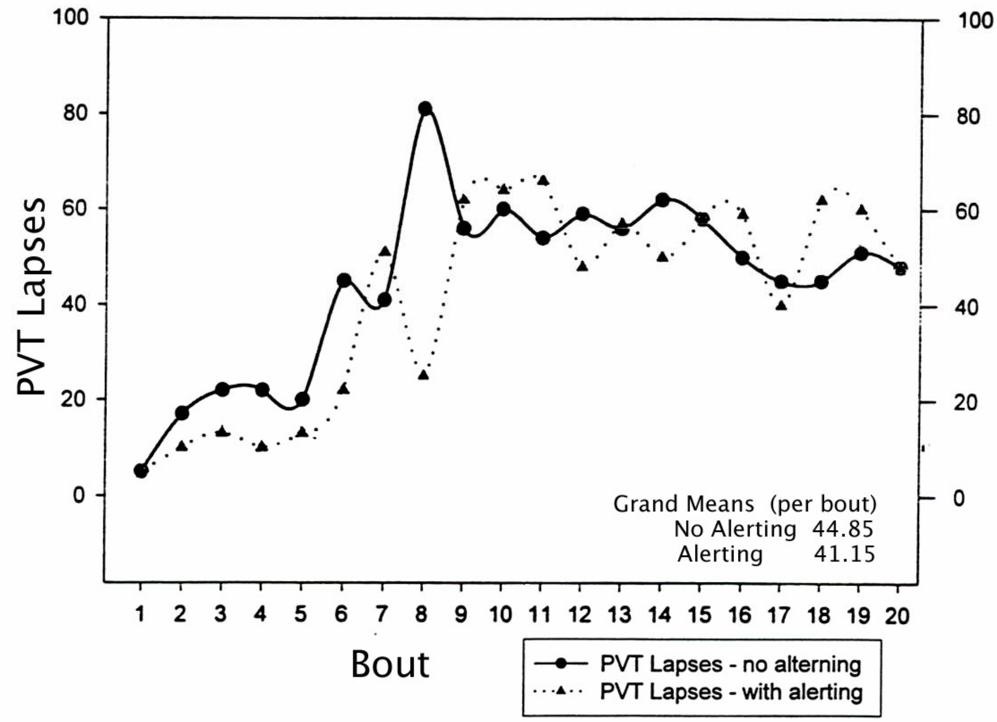

FIGURE 3 Time course of vigilance deterioration for a single subject sleep deprived twice several months apart, once without alerting stimuli and once with alerting stimuli (Dinges et al. 1998).

rather than process-based. A future application of alertness monitoring technologies could be to measure driver vigilance as part of a performance-based alertness standard.

In addition to the studies discussed above, a number of significant studies focusing on specific aspects of commercial driver fatigue have been published in recent years. These include studies of a 14–10 schedule and loading and unloading on driver fatigue (Krueger and Van Hemel, 2001), operational scheduling practices and their effects on driver fatigue, driver rest and recovery (O'Neill et al., 1999), sleeper berth use (Dingus et al., 2001), local–short-haul driver fatigue (Hanowski et al., 2000), large-truck crash rate by hour of day (Hendrix, 2002), and motor coach driver fatigue (FHWA, 1999; Brock et al., 2005).

MACROERGONOMICS AND SAFETY MOTIVATION

As noted, human factors (also called ergonomics) is the science of human performance in systems. Traditional ergonomic studies of the interactions of humans with systems focus on the physical and psychomotor human-machine interface, i.e., in the case of motor vehicle transportation, interactions between the driver, vehicle, traffic, and highway. For non-commercial drivers, focusing on these physical and psychomotor interactions may suffice since these drivers are not a part of any larger, organized system other than the highway itself. But for commercial drivers, focusing on physical and psychomotor interactions alone is clearly insufficient to understand the human–system interface in its entirety. Commercial drivers operate a vehicle on a highway, but they also operate within an organizational structure, with important interactions with fleet managers, dispatchers, their pay system, and customers. Moreover, this industry operates within a regulatory regime that further characterizes and shapes the system. Macroergonomics, in particular as defined and promulgated by Hal W. Hendrick (Hendrick and Kleiner, 2001), is the science of human factors design of entire organizational systems, as opposed to microergonomics, which focuses on physical human–system interactions. In the case of commercial driving safety, macroergonomics might focus on the processes, interactions, and contingencies associated with the management and operational world as experienced by the driver (e.g., dispatch, delivery schedule demands, pay method), and on resulting safety-related attitudes, motivations, and behaviors. The purpose of macroergonomic assessment is to enhance carrier and driver safety motivation, practices, and outcomes by helping to develop systematic, top-down, harmonized approaches to motor carrier organizational and work systems design.

One macroergonomic approach is to develop carrier management methods to increase driver safety motivation. A good example is provided by behavior-based safety (BBS). BBS is a method to engage workers in the improvement process, teach them to identify and observe critical safety behaviors, provide feedback to encourage improvement, and use gathered data to target system factors for positive change (Krause, Robin, and Knipling, 1999; Knipling et al., 2003). BBS combines applied behavior analysis, behavior modification, quality management, organization development, and risk management. BBS has demonstrated success in the prevention of occupational accidents and injuries, mostly in manufacturing and maintenance settings. Guastello (1993) reviewed 53 occupational safety and health studies and found that the application of BBS resulted in an average injury reduction rate of 60%.

Unfortunately, the key BBS methods of direct behavioral observation and feedback are not practicable in most CMV operational settings. The work of commercial drivers is largely solitary and geographically removed from their home work station. One variation of BBS, intended for situations where employees work alone (such as commercial driving), is self-management. Hickman and Geller (2003) taught self-management strategies to short-haul truck drivers at two trucking terminals. Techniques included identification of antecedents and consequences of at-risk driving behaviors, self-observation and monitoring, self-rewards for correct safety behavior, and subsequent peer support. The results were promising and indicate that this approach help to increase driver safety motivation.

The role of driver human factors must be considered in the context of the whole transportation system. Such factors as the changing demographics of the U.S. workforce and working conditions in the truck and bus industry can have a significant influence on safe CMV safety. New human factors strategies may be required to meet the demand for new drivers to replace retiring drivers, meet industry growth projections, and reduce driver churning that occurs from drivers changing jobs. Improving driver retention may be one of the keys to attracting new entrants to the occupation, since by definition high turnover usually signifies unsatisfactory conditions. While most driver shortage studies have surveyed drivers who changed jobs to determine what they did not like, one study (Gallup, 1997) interviewed 801 drivers who had been with their current company for at least 5 years to determine what factors were most significant in promoting job satisfaction. Five specific job attributes emerged as the most important predictors of overall satisfaction:

- Steadiness of work (consistent driving assignments),
- Genuine care of managers for their drivers,
- Pay,
- Support from company while on the road, and
- Numbers of hours worked.

Driving a CMV is undeniably a challenging and difficult profession and lifestyle. The physical rigors of the job may be compounded by perceived or real poor treatment from managers, dispatchers, shippers, receivers, and others. These problems are probably experienced more commonly in for-hire companies than in private companies. Improved working conditions increase the job satisfaction of drivers and improve driver retention within fleets, which in turn enhances driver safety (Staplin et al., 2003).

Needed research includes studies of ways to redesign and enrich the truck driver job, including such approaches as career paths, to encourage driver retention and to attract non-traditional sources of labor to the occupation. Women are a major potential nontraditional source of drivers; a study is needed of female commercial drivers and factors that influence their decisions to remain in the occupation or to leave it.

RESEARCH NEEDS

This section discusses needs for new knowledge (research) and new tools (development) relating to commercial driver human factors. As noted at the beginning of this chapter, there are numerous demographic, medical, personality, and performance traits that appear to correlate with commercial driver crash risk. These factors and their relation to driving safety need to be better understood and quantified. Identification of the most predictive of these measures and development of better instruments for measuring them would improve the selection and safety management of commercial drivers. One way to generate such data would be a case control methodology whereby personality, medical, and behavioral profiles are obtained for a group of drivers and then compared with measures of crash risk (crashes, violations, incidents) within the same group. Currently, FMCSA is planning such a driver risk factor study.

R&D needs related to driver functional capabilities include the following:

- Investigate multidimensional testing devices that provide reliable performance assessments of a combination of attention and visual functions, yet are able to capture the complexities associated with driving and thus predict driving performance.
- Investigate the feasibility of training and practice to mitigate against deteriorating dynamic visual acuity, decision making, depth perception, and useful field of view. Develop research protocols that indicate not only whether an intervention works, but how, why, and under what circumstances.
- Conduct studies using naturalistic driving and other improved criterion measures to better quantify the relationships of driver abilities with safe driving measures.
- Investigate ways to integrate safe driving measures with improved driver selection tests and on-the-job performance criteria.

In addition to vehicle, traffic, roadway environment, and situational factors, an array of personal factors underlie individual driver crash risk. A pressing R&D need is the systematic and quantitative determination of the role that these personal factors (e.g., medical, performance, personality, demographic, and behavioral history) play in commercial driver risk. Studies of commercial driver characteristics potentially associated with crash risk could identify robust trait measures or define the need for improved measures. A systematic way to quantify and compare personal risk factors would be to measure multiple factors in a large and representative group of drivers, and then empirically determine the relation of each factor to commercial driver crash, violation and incident involvement. Both prospective (after subject measurement) and retrospective (prior to measurement) comparisons to criterion safety measures could be made. The case-control design is a way to quantify the association of each factor studied with the probability of crash or incident involvement (Boyle et al., 2002). In addition to quantifying individual risk factors, a study employing this design could derive optimal combinations of multiple factors for predicting driver risk. Study data could support the development or validation for driver selection tools, and, at the same time, capture situational and environmental factors associated with elevated crash risk or interacting with personal factors to accentuate risk. As noted, FMCSA is planning a case control study to address many such factors.

In the area of driver fatigue and alertness, there are many research questions to be answered as well as countermeasure development opportunities. R&D needs include

- Postimplementation assessment of the influence of the new HOS rules in both the United States and Canada. In particular, determine
  - Alertness benefits from the extended 10-h daily off-duty period;
  - Whether the daily increase in driving time from 10 to 11 h (in the United States) introduces significant increased risk;
  - The nature of the interactions among amount of sleep (including naps), hours driving/working, and hour-of-day;
  - Whether the restart period of 34 h off-duty is sufficient for drivers to recover fully from a week's work and, in addition, determine the long-term job satisfaction and quality-of-life impacts of the rule for drivers who use short restarts frequently;
  - Acceptable and optimal ways to split off-duty periods in the sleeper berth; and
  - In both the United States and Canada, comprehensive evaluation of the total rule to demonstrate net benefits in comparison to the previous rule.
- Determination of the relationship between driver alertness level (e.g., as measured by PERCLOS or other validated alertness measure) and the occurrence of driver errors and crashes. As individual measures and associated sensors are validated and refined, there is the opportunity to combine multiple measures and sensors to increase the accuracy and effectiveness of onboard alertness and performance monitoring.
- Examination of the effects of night driving schedules and development of practical screening tests to identify persons not well suited to night driving.
- Further examination of the effects of rest breaks and naps (including schedule and duration) driving performance. Both day and night driving should be addressed, as should sleep and rest obtained in moving versus stationary vehicles.
- Determination of the incidence and range of circadian variance. Are there true "owl" and "lark" physiological traits, or do these apparent variations merely reflect sleep habits?

- Investigation of methods to improve the quality of sleep in sleeper berths, in both moving and stationary trucks.
- Documentation and quantification of the apparently large and enduring individual differences in susceptibility to driver fatigue, and determine ways to identify the most at-risk individuals.
- Practical methods to improve driver fatigue management, both in the context of compliance with HOS regulations and proactive practices beyond compliance. This might include the development of a toolbox for improving CMV driver fatigue management and self-management similar to one developed and promulgated for transit operators (Gertler et al., 2002).

R&D needs relating to driver training include a scientifically rigorous experimental demonstration of the value of formal commercial driver training and various specific techniques employed in commercial driver training. Also, studies of driver performance during training and testing could determine identify training and testing performance measures having the greatest predictive validity in relation to safety performance on the job. Many outstanding questions exist relating to commercial driver training using simulation or other training technologies like computer-based training. For example, does the use of simulators permit finer measurement of driver safety behavior, performance, and style and thereby enable more accurate predictions of driver safety on the job?

For better or worse, worker safety behaviors are influenced by the social and economic environment of the workplace as well as specific positive and negative contingencies (rewards and punishments) associated with those safety behaviors. Unlike the general population of drivers, commercial truck and bus drivers typically drive within an organizational milieu (e.g., schedule demands, pay methods) as well as a government regulatory and enforcement structure (e.g., HOS). Both carrier management and government practices have the potential to promote cooperation and safety or to provoke negative attitudes and resistance. Research into commercial driver safety attitudes and motivation may help ensure that management and government safety interventions are accepted by drivers and result in safer behaviors.

REFERENCES

American Trucking Associations. *American Trucking Trends 2004*. ATA, Alexandria, Va., 2004.

ATA Foundation. *SafeReturns: A Compendium of Injury Reduction and Safety Management Practices of Award Winning Carriers*. ATAF Publication No. C0938. ATA, 1999.

Balkin, T. J., D. Thorne, H. Sing, M. Thomas, D. P. Redmond, N. Wesensten, M. Russo, J. Williams, S. Hall, and G. L. Belenky. *Effects of Sleep Schedules on Commercial Motor Vehicle Driver Performance*. FMCSA Technical Report No. DOT-MC-00-133. FMCSA, U.S. Department of Transportation, 2000.

Blower, D. *The Relative Contribution of Truck Drivers and Passenger Car Drivers to Two-Vehicle, Truck–Car Traffic Crashes*. Publication No. UMTRI-98-25. University of Michigan Transportation Research Institute, Ann Arbor, 1998.

Blower, D. F. *The Accident Experience of Younger Truck Drivers*. Final report. University of Michigan Trucking Research Institute and the Great Lakes Center for Truck and Transit Research, Ann Arbor, 1996.

Blower, D. F. and K. L. Campbell. *Methodology of the Large Truck Crash Causation Study*. Large Truck Crash Causation Study Analysis Series. Report No. FMCSA-RI-05-035. FMCSA, U.S. Department of Transportation, 2005.

Boyle, L., N. Meltzer, J. Hitz, and R. Knipling. Case-Control Study of Large Truck Crash Risk Factors. *Proc., International Truck and Bus Safety and Policy Symposium*. Center for Transportation Research, University of Tennessee, and National Safety Council, Knoxville, 2002, pp.163–174.

Brewster, R. M., D. F. Dinges, G. Maislin, G. P. Krueger, and R. J. Carroll. Pilot Test of Fatigue Management Technologies. *Transportation Research Record: Journal of the Transportation Research Board, No. 1922,* Transportation Research Board of the National Academies, Washington, D.C., 2005, pp. 175–182.

Brock, J. F., G. A. Golembiewski, G. P. Krueger, C. Daecher, R. Bishop, and G. Bergoffen. *CTBSSP Synthesis of Safety Practice 7: Motorcoach Industry Hours of Service and Fatigue Management Techniques*. Transportation Research Board of the National Academies, Washington, D.C., 2005.

Cleaves, E. The Sharpening: Improving Your Drivers' Knowledge and Skills. *Chilton's Commercial Carrier Journal for Professional Fleet Managers*, Vol. 154, No. 11, 1997, pp. 58–62.

Council, F. M., D. L. Harkey, A. J. Khattak, and Y. M. Mohamedshah. Examination of Fault, Unsafe Driving Acts, and Total Harm in Car–Truck Collisions. *Transportation Research Record: Journal of the Transportation Research Board, No. 1830*, Transportation Research Board of the National Academies, Washington, D.C., 2003, pp. 63–71.

Dinges, D. F. The Promise and Challenges of Technologies for Monitoring Operator Vigilance. *Proc., Managing Fatigue in Transportation Conference,* Tampa, Fla., 1997, pp. 77–84.

Dinges, D. F. Human Performance, Capability, and Behavior. Presented at FMCSA–TRB Truck and Bus Research Futures Conference, Arlington, Va., March 23–24, 2005.

Dinges, D. F., M. M. Mallis, G. M. Maislin, and J. W. Powell. Evaluation of Techniques for Ocular Measurement as an Index of Fatigue and the Basis for Alertness Management. NHTSA Report No. DOT HS 808 762. NHTSA, U.S. Department of Transportation, 1998.

Dingus, T. A., V. L. Neale, et al. *Impact of Sleeper Berth Usage on Driver Fatigue*. FMCSA Report No. RT-02-050. FMCSA, U.S. Department of Transportation, 2001.

Dohm, A. Gauging the Labor Force Effects of Retiring Baby-Boomers. *Monthly Labor Review,* Bureau of Labor Statistics, U.S. Department of Transportation, July 2000.

Dueker, R. L. *Assessing the Adequacy of Commercial Motor Vehicle Driver Training: Final Report Volume 1: Executive Summary*. Applied Science Associates, Inc., July 1995. (Also available as Docket Document FMCSA-97-2199-148.)

Emery, C., J. Robin,R. R. Knipling, R. Finn, and S. Fleger. *Research Design: Validation of Simulation Technology in the Training, Testing, and Licensing of Tractor-Trailer Drivers*. FHWA Final Report FHWA-MC-99-060. FHWA, U.S. Department of Transportation, 1999.

FHWA. *Model Curriculum for Training Tractor-Trailer Drivers: Administrator's Manual*. Government Printing Office, GPO Stock No. 050-001-00293-1. FHWA, U.S. Department of Transportation, 1985.

FHWA. *Bus Driver Fatigue and Stress Issues Study*. Final report. FHWA, U.S. Department of Transportation, 1999.

FMCSA. *Report to Congress on the Large Truck Crash Causation Study*. FMCSA, U.S. Department of Transportation, 2006.

Gallup Organization. *Empty Seats and Musical Chairs: Critical Success Factors in Truck Driver Retention*. ATA Foundation, Alexandria, Va., 1997.

Gertler, J., S. Popkin, D. Nelson, and K. O'Neill. *TCRP Report 81: Toolbox for Transit Operator Fatigue*. TRB, National Research Council, Washington, D.C., 2002.

Guastello, S. J. Do We Really Know How Well Our Occupational Accident Prevention Programs Work? *Safety Science*, Vol. 16, 1993, pp. 445–463.

Guido, D. W. TRB Panel Targets Pay to Woo More Drivers. *Transport Topics,* January 17, 2005.

Hanowski, R. J., W. W. Wierwille, S. A. Garness, and T. A. Dingus. *Impact of Local/Short Haul Operations on Driver Fatigue.* Final Report No. DOT-MC-00-203. FMCSA, U.S. Department of Transportation, 2000.

Hartman, K., R. Pritchard, K. Jennings, J. Johnston, R. R. Knipling, J. MacGowan, L. Oliphant, M. Onder, and C. Sanft. *Commercial Vehicle Safety—Technology and Practice in Europe*. FHWA-PL-00-010, FHWA, U.S. Department of Transportation, 2000.

Hartley, L., T. Horberry, N. Mabbott, and G. A. Krueger. *Review of Fatigue Detection and Prediction Technologies*. National Road Transport Commission, Melbourne, Australia, 2000.

Hendrick, H. W., and B. M. Kleiner. *Macroergonomics: An Introduction to Work System Design*. Human Factors and Ergonomic Society, 2001.

Hendrix, J. Fatal Crash Rates for Tractor-Trailers by Time of Day. *Proc., International Truck and Bus Safety and Policy Symposium*. Center for Transportation Research, University of Tennessee, and National Safety Council, Knoxville, 2002, pp. 237–250.

Hickman, J. S., and E. S. Geller. A Self-Management for Safety Intervention to Increase Safe Driving Among Short-Haul Truck Drivers. *Journal of Organizational Behavior Management,* Vol. 23, No. 4, 2003, pp. 1–20.

Horn, B. E., and L.-P. Tardif. Licensing and Training of Truck Drivers. *IATSS Research*, Vol. 23, No. 1, 1999, pp.16–25.

Itoi, A., R. Cilveti, M. Voth, D. Bezalel, P. Hyde, A. Gupta, and W. C. Dement. *Can Drivers Avoid Falling Asleep at the Wheel? Relationship Between Awareness of Sleepiness and Ability to Predict Sleep Onset*. AAA Foundation for Traffic Safety, February 8, 1993.

Knipling, R. R. Individual Differences in Commercial Driver Fatigue Susceptibility: Evidence and Implications. Presented at Fatigue Management in Transportation Operations International Conference, Seattle, Wash., September 11–15, 2005.

Knipling, R. R., A. Alvarez, R. J. Carrol, J. L. Robin, and P. J. Roke. Commercial Driver Human Factors R&T at the FMCSA. *Proc., Third International Large Truck and Bus Safety Symposium*, Knoxville, Tenn., April 3–5, 2002.

Knipling, R. R., L. N. Boyle, J. S. Hickman, J.S. York, C. Daecher, E. C. B. Olsen, and T. D. Prailey. *CTBSSP Synthesis of Safety Practice 4: Individual Differences and the High-Risk Commercial Driver*. Transportation Research Board of the National Academies, Washington, D.C., 2004b.

Knipling, R. R., J. S. Hickman, and G. Bergoffen. *CTBSSP Synthesis of Safety Practice 1: Effective Commercial Truck and Bus Safety Management Techniques*. Transportation Research Board of the National Academies, Washington, D.C., 2003.

Knipling, R. R., and T. T. Shelton. Problem Size Assessment: Large Truck Crashes Related Primarily to Driver Fatigue. *Proc., Second International Large Truck Safety Symposium*. University of Tennessee Transportation Center, Knoxville, 1999, pp. 3–12.

Knipling, R. R., P. F. Waller, R. C. Peck, R. Pfefer, T. R. Neuman, K. L. Slack, and K. K. Hardy. *NCHRP Report 500: Guidance for Implementation of the AASHTO Strategic Highway Safety Plan; Volume 13: A Guide for Addressing Heavy Truck Crashes*. Transportation Research Board of the National Academies, Washington, D.C., 2004a.

Kostyniuk L. P., F. M. Streff, and J. Zakrajsek. *Identifying Unsafe Driver Actions that Lead to Fatal Car–Truck Crashes*. AAA Foundation for Traffic Safety, Washington D.C., 2002.

Krause, T. R., J. L. Robin, and R. R. Knipling. *The Potential Application of Behavior-Based Safety in the Trucking Industry*. Report No. FHWA-MC-99-071. FHWA, U.S. Department of Transportation, 1999.

Krueger, G. P., and S. B. Van Hemel. *The Effects of Loading and Unloading Cargo on Commercial Truck Driver Alertness and Performance*. Report No. DOT-MC-01-107. FMCSA, U.S. Department of Transportation, 2001.

Lancaster, R., and R. Ward. *The Contribution of Individual Factors to Driving Behaviour: Implications for Managing Work-Related Road Safety*. Entec UK Limited, Health and Safety Executive, Research Report 020, United Kingdom, 2002.

Lin, T., P. Jovanis, and C. Yang. Time of Day Models of Motor Carrier Accident Risk. *Transportation Research Record 1467*, TRB, National Research Council, Washington, D.C., 1994, pp. 1–8.

Llaneras, R. E., R. W. Swezey, J. F. Brock, H. P. Van Cott, and W. C. Rogers. *Research to Enhance the Safe Driving Performance of Older Commercial Vehicle Drivers*. NTIS PB96-176839. FHWA, U.S. Department of Transportation, Washington, D.C., 1995.

McCartt, A. T, J. W. Rohrbaugh, M. C. Hammer, and S. Z. Fuller. Factors Associated with Falling Asleep at the Wheel Among Long-Distance Truck Drivers. *Accident Analysis and Prevention*, Vol. 32, 2000, pp. 493–504.

NHTSA. *Traffic Safety Facts: Older Population*. DOT HS 809 328. NHTSA, U.S. Department of Transportation, 2000.

NHTSA. *Traffic Safety Facts 2002*. DOT HS 809 608. NHTSA, U.S. Department of Transportation, 2003.

NTSB. *Safety Study: Fatigue, Alcohol, Other Drugs, and Medical Factors in Fatal-to-the-Driver Heavy Truck Crashes*. Report No. NTSB/SS-90/02. NTSB, U.S. Department of Transportation, 1990.

Olson, R .L., J. S. Hickman, R. R. Knipling, R. J. Hanowski, and R. J. Carroll. Factors and Driving Errors Associated with Fatigue in a Naturalistic Study of Commercial Drivers. Presented at Fatigue Management in Transportation Operations International Conference, Seattle, September 11–15, 2005.

O'Neil, T. R., G. P. Krueger, S. B. Van Hamel, and A. L. McGowan. *Effects of Operating Practices on Commercial Driver Alertness*. FHWA-MC-99-140. FHWA, U.S. Department of Transportation, 1999.

Park, S.-W., A. Mukherjee, R. Gross, and P. P. Jovanis. Safety Implications of Multiday Driving Schedules for Truck Drivers: Comparison of Field Experiments and Crash Data Analysis. *Transportation Research Record: Journal of the Transportation Research Board, No. 1922*, Transportation Research Board of the National Academies, Washington, D.C., 2005, pp. 167–174.

Professional Truck Driver Institute. Curriculum Standard Guidelines for Entry-Level Tractor-Trailer Driver Courses. Available at www.ptdi.org. Accessed September 10, 1999.

Robin, J. L., R. R. Knipling, S. A. Tidwell, J. McFann, M. L. Derrickson, and C. Antonik. FMCSA Commercial Truck Simulation Validation Study Phase I Pilot Test: Driving Scenario Definition and Development. Presented at Driving Simulation Conference North America 2005, Orlando, Fla., November 30–December 2, 2005.

Staplin, L., K. Gish, L. Decina, and R. Brewster. *Commercial Motor Vehicle Driver Retention and Safety*. Report No. FMCSA-RT-03-004. FMCSA, U.S. Department of Transportation, 2003.

Staplin, L., K. H. Lococo, L. Decina, and G. Bergoffen. *CTBSSP Synthesis of Safety Practice 5: Training of Commercial Motor Vehicle Drivers*. Transportation Research Board of the National Academies, Washington, D.C., 2004.

Swezey, R. W., and D. H. Andrews (eds.). *Readings in Training and Simulation: A 30-Year Perspective*. Human Factors and Ergonomic Society, Santa Monica, Calif., 2001.

Treat, J. R., N. S. Tumbas, S. T. McDonald, D. Shinar, R. D. Hume, R. E. Mayer, R. L. Stansifer, and N. J. Catellan. *Tri-Level Study of the Causes of Traffic Accidents: Final Report Volume I: Causal Factor Tabulations and Assessments*. DOT HS-805 085. Institute for Research in Public Safety, Indiana University, 1979.

Van Dongen, H. P. A., M. D. Baynard, G. Maislin, and D. F. Dinges. Systematic Inter-Individual Differences in Neurobehavioral Impairment from Sleep Loss: Evidence of Trait-Like Differential vulnerability. *Sleep*, Vol. 27, No. 3, 2004, pp. 423–433.

Wierwille, W. W., S. S. Wreggit, C. L. Kirn, L. A. Ellsworth, and R. J. Fairbanks. *Research on Vehicle-Based Driver Status/Performance Monitoring; Development, Validation, and Refinement of Algorithms for Detection of Driver Drowsiness*. VPISU Report No. ISE 94-04; NHTSA Report No. DOT HS 808 247. Vehicle Analysis and Simulation Laboratory, Virginia Polytechnic Institute and State University, 1994.

Wylie, C. D., T. Shultz, J. C. Miller, M. M. Mitler, and R. R. Mackie. *Commercial Motor Vehicle Driver Fatigue and Alertness Study*. FHWA, U.S. Department of Transportation, 1996.

Zacharia, Z. G., and S. H. Richards. *2002 International Truck & Bus Safety Research & Policy Symposium: Executive Summary*. Center for Transportation Research, University of Tennessee, Knoxville, and National Safety Council, 2002.

Carrier Safety Management

Gene Bergoffen
Roger D. Clarke
Deborah M. Freund
David F. Melton

The CMV operations safety literature generally recognizes that a very important element in achieving motor carrier safety is motor carrier management (Moses and Savage, 1994). Whether the motor carrier is a one-person owner–operator or a fleet of thousands of tractors and trailers, management determines whether the carrier operates safely or not. Management selects, trains, supervises, motivates, disciplines, and compensates drivers. Management makes the equipment purchase and maintenance decisions. Management sets the entire safety tone of the enterprise both explicitly through formal policies and implicitly in the way that it treats potential rule breaking and other unsafe practices.

In keeping with the general thrust of this circular, the focus in this chapter is on management practices that affect highway safety. Occupational and environmental safety practices, while also important, are beyond the scope of this review.

This chapter addresses carrier safety fitness. It examines both mandatory and voluntary approaches to safety management, and looks at the characteristics of a safe motor carrier. The chapter also describes additional research needs.

CARRIER SAFETY FITNESS: FEDERAL AND STATE MANDATES

Within the United States, motor carriers that travel across state lines are subject to a regime of mandatory federal safety regulations relating to vehicles and drivers and are subject to oversight and review by federal and cooperating state officials. Intrastate operations are subject to state regulations. These requirements, and the associated information systems that record and measure safety performance, often influence safety management by fleet operators, as the fleet operation must be rated as satisfactory or meet defined performance requirements to continue to operate without suspension or a higher degree of continuing oversight by federal and state officials. The safety fitness standards are spelled out in Title 49 CFR, Part 385, specifically §385.5.

To meet safety fitness standards, motor carriers must demonstrate that they have adequate safety management controls in place to ensure acceptable compliance with requirements that reduce the risks associated with certain driver activities and behavior, company financial responsibility, and maintenance of vehicles.

FMCSA is the federal agency charged with implementation of safety fitness standards. Beginning in the mid-1990s, FMCSA developed an information tool for analyzing safety performance: the Motor Carrier Safety Status Measurement System, or SafeStat. The SafeStat database is accessible through the agency's website (www.fmcsa.dot.gov). SafeStat provides information on motor carrier safety by reporting each listed carrier's crash, inspection, compliance review, violation, and out-of-service and enforcement history based on travel within the United States (not Canadian travel). SafeStat helps carriers measure their own safety performance and evaluate their competition and provides a foundation for FMCSA actions to target unsafe motor carriers for compliance actions.

FMCSA recently found that carriers designated as at-risk had crash rates that were more than double those of their competitors not identified as safety risks (Volpe Center, 2004).

Findings on SafeStat indicators could serve logically as a basis for support of continued focus by FMCSA on higher-risk carriers to achieve improved carrier safety management. Effectiveness of federal and associated state enforcement programs toward this end has been investigated to a significant degree in the past several years. A compendium of research findings —generally supporting compliance and enforcement activity—is found at this location on the FMCSA website: www.fmcsa.dot.gov/safetyprogs/research/researchpubs.htm#AB.

CARRIER-DRIVEN PRACTICES AND SELF-ASSESSMENT

Beyond compliance with governmental requirements, a number of voluntary, management-driven safety management and certification systems and approaches are evolving within the CMV operations community. Five selected studies and survey projects highlight these approaches:

- ATRI. *Safe Returns: A Compendium of Injury Reduction and Safety Management Practices of Award Winning Carriers.* ATRI publication No. C0938, 1999(a).
- ATRI. *Truck Driver Risk Assessment Guide and Effective Countermeasures; Recommended Management Practices,* 1999(b).
- Corsi, T. M., and R. E. Barnard. *Best Highway Safety Practices: A Survey of the Safest Motor Carriers About Safety Management Practices.* Final report. FMCSA Contract No. DTFH61-98-X-00006, 2003.
- Knipling, R. R., J. S. Hickman, and G. S. Bergoffen. *CTBSSP Synthesis of Safety Practice 1: Effective Commercial Truck and Bus Safety Management Techniques.* Transportation Research Board of the National Academies, Washington, D.C., 2003.
- Stock, D. *I-95 Corridor Coalition Field Operational Test 10: Coordinated Safety Management, Vol. I: Best Practices in Motor Carrier Safety Management*. Final report. 2001.

Carrier Safety Management Practices

The approaches and findings of the above studies and surveys are generally consistent, and the practices included follow similar patterns and components. The following is a general summary of those practices that characterize fleets that are dedicated to safety management and whose safety performance exceeds the norm (e.g., lower crash and out-of-service rates):

- Management commitment: Safety management for "best practice" carriers begins with clear and unequivocal support of top management, and integration of safety focus in all aspects of operations. Committed managers use a comprehensive approach across all aspects of operations, with safety a number one priority. Safety-oriented leaders make it clear that cost is not a driving factor in making safety decisions and encourage and enable employee communications about safety concerns.

- Driver hiring practices: Although the criteria used by safety committed fleets vary, the following practices are commonly used by these fleets:
  - In-person application requirements,
  - Screening of employment history,
  - Minimum experience levels,
  - Hiring based on criteria relating to driver crash, violation, or incident history,
  - Driving tests,
  - Physical exams, and
  - Personal interviews, and personality tests.

The cost to hire new commercial drivers varies according to whether novice or experienced drivers are recruited, but in either case the time and expense justify selecting the best candidates with the greatest chances for long term safe driving performance. One approach that bus and trucking companies have used to understand whether a candidate has the attitude and willingness to perform the driving job is driver profiles. There are a number of paper and pencil psychological tests available (ATA Foundation, 1999) that attempt to measure candidate characteristics such as interest and willingness to perform tasks essential to commercial driving; response to situations commercial drivers face; intelligence, factual knowledge, and personality; service orientation, stress tolerance, and reliability; and social adjustment, ambition, and prudence. The best of these scales are based on task analyses of the segment of the truck or bus industry of interest and validated by a panel of expert drivers. The prospective driver is, in effect, benchmarked against successful drivers.

- Employee training: All CMV drivers must hold a CDL, but in the United States there are no comprehensive mandatory training standards for entry-level CMV drivers. However, FMCSA recently published a final rule establishing standards for mandatory training requirements on four specific topics:
  - Driver medical qualification and drug and alcohol testing,
  - Driver HOS rules,
  - Driver wellness, and
  - Whistleblower protection.

Many safety-oriented fleet managers do not rely entirely on preservice training for drivers and supplement training with fleet-based training. Among the approaches these companies use are the following:

- Standardized training for all new hires, including company policies, customer relations, defensive driving, rules for driving;
- Apprenticeship and “finishing” programs for new drivers;
- Regular refresher training for both new and experienced drivers;
- Regularly scheduled safety meetings; and
- Remedial training for problem drivers.

- Encouraging and reinforcing safe driver behavior. A number of activities and practices used by safely managed fleets fall under this category:
  - Driver incentive programs: these can include awards for safe performance, such as bonuses, recognition, and other tangible and intangible awards.
  - Disciplining: the bases for discipline include noncompliance with regulations, violation of company safety policies, and unsafe driving behavior.
  - Fatigue management programs: these programs range from careful oversight of scheduling and dispatching, “alertness-friendly” scheduling for drivers, intensive

education, and open communication between drivers and dispatchers about driver conditions in relation to assignments.

- Fatigue management programs (FMPs): FMPs, as opposed to HOS rules, have received considerable emphasis in Australia (Transport Regional Policy Section, 1998; National Road Transport Commission, 2003). In Canada, a FMP is under way in Alberta and Quebec in a cooperative effort between the trucking industry and government. FMCSA has now joined this project, and it has been named the North American Fatigue Management Program. Most recently, the Research and Special Programs Administration released a multimodal fatigue management reference manual (*Fatigue Management Reference*, 2003), and TCRP published a toolbox for transit operator fatigue (Toolbox, 2003). In general, fleet-based FMPs incorporate fatigue and wellness education, medical evaluation (emphasizing sleep apnea screening), and improved scheduling practices. The basic principles for managing fatigue in CMV operations are
  - Plan schedules to maximize the opportunity for sleep and rest at the time they are most needed and are likely to be most effective (e.g., at night).
  - Build in time to schedules for typical delays and disruption.
  - Limit the buildup of fatigue by having at least 1 day a week free of work.
  - Compensate for the lack of night sleep on a regular basis with breaks between schedules that allow at least two consecutive nighttime sleeps.
  - Compensate for shorter sleep opportunity in 1 day with a longer sleep opportunity the next day.
  - Balance a long shift on 1 day with more rest at the end of the shift and a shorter shift on the next day.
  - Understand there is a limit to this balancing and the minimum opportunity for sleep of at least 7 to 8 h per day should not be continually compromised by work demands.
  - Use short breaks and naps, and to a lesser degree food, coffee, and exercise, as short-term measures, knowing their limitations.
  - Understand that personal awareness of tiredness and fatigue is never a substitute for a work pattern that allows opportunity for sleep.
  - Understand that schedules should take into account the requirements of daily living, e.g., eating, hygiene, getting to and from base, and family life.
  - Medical screening and facilitation of treatment should be part of any systematic carrier FMP.
- Driver wellness programs: Many fleets offer some wellness services to their drivers and have developed and offered organized wellness training. Also included are medical screening and counseling programs for driving-related conditions.
- BBS methods: BBS is a set of methods to improve safety performance by teaching workers to identify critical safety behaviors, provide feedback, and use gathered data to target factors to implement change (Knipling, Hickman, and Bergoffen, 2003). The *Synthesis Report on Effective Commercial Truck and Bus Safety Management Techniques* reported that many fleet safety managers use BBS techniques, but it is not clear whether the managers employ comprehensive BBS strategies and tactics.
- Monitoring driver performance: Safety managers monitor driver behavior to ensure performance stays within the bounds of safety. Past performance is considered a predictor of future safety results. A number of techniques are employed to track driver safety performance.

– Observation of driving behavior through ride-alongs. Surveys indicate that a significant number of safety managers, especially those in larger fleets, use in-service observations to monitor driver behavior (Stock, 2001).

– Continuous tracking of driver's crashes–incidents–violations. FMCSA carrier profiles, available from the agency's analysis and information website, provide this information, along with self-reporting requirements employed by many fleets.

– Tracking of overall fleet safety statistics. This information, also available online from the FMCSA website, is an indicator of systemic management effectiveness.

– Onboard monitoring and recording. Various tracking devices are available to monitor speed, braking, HOS compliance, acceleration, and other technical parameters. Many fleets employ speed limiters on their vehicles.

– Safety placards. These include "how's my driving?" signs and placards which invite feedback to fleet safety managers on risky behavior of fleet drivers. The feedback, when verified, can be a basis for communications to the driver, both for improved performance, or commendation.

– Accident investigation. This includes management visits to crash sites, in-house reviews, determination of fault and preventability, with specific feedback to the driver on results and appropriate future actions to prevent recurrent events.

• Employee retention programs: Because of unfavorable demographics, in terms of attracting new drivers, one approach to solving some of the looming driver shortage is driver retention. Particularly, there is a strong desire to retain drivers who have exhibited the ability to perform safely. A large and important segment of the trucking industry is the truckload segment, which hauls 68% of the tonnage and has an 86% share of the revenue (ATA, 2003). Truckload drivers are often away from home for several weeks at a time, sleep in the cabs of their trucks, work up to 70 h in 8 days, and earn on average $36,000 annually (Belzer et al., 2002). Truck drivers in the truckload segment change jobs often, and it is common for the large, national companies to experience annual driver turnover rates of 100% or greater, although the average truckload turnover rate in 1999 was 69% (ATA, 2000)

Fleet safety managers recognize that the cost of training and integrating new drivers is often higher than efforts to retain current employees. Numerous industry studies over the past decade have shown that new human factors strategies are required to meet the sheer size of the demand for new drivers to replace retiring drivers, meet industry growth projections, and reduce driver churning that occurs from drivers changing jobs. While most driver shortage studies have surveyed drivers who changed jobs to determine what they did not like, one study (Gallup, 1997) interviewed 801 drivers who had been with their current company for at least 5 years to determine what factors were most significant in promoting job satisfaction. Five specific job attributes emerged as the most important predictors of overall satisfaction:

– Steadiness of work (consistent driving assignments),
– Genuine care of managers for their drivers,
– Pay,
– Support from company while on the road, and
– Numbers of hours worked.

In addition to the awards programs discussed the above section, fleets also focus on actions to improve equipment and cab ergonomics, amenities such as PrePass and other electronic clearance systems, scheduling to increase time at home, and benefit programs.

- Vehicle maintenance and inspection: *Safe Returns* (ATRI, 1999a) points out that safety-conscious fleets employ practices that emphasize proper vehicle maintenance. These include the following:
  - Compliance with federal and state requirements—these practices include pretrip, posttrip, and annual vehicle inspections.
  - Trip sheets—these include driver documentation of pretrip and posttrip maintenance inspections to ensure follow-up.
  - Computerized equipment maintenance—many carriers use computerized programs to collect data to develop proper equipment specifications, track maintenance activities, monitor equipment performance, and schedule equipment repairs.
  - Outsourcing of maintenance sctivities—a majority of fleets outsource one or more of their maintenance activities (Corsi and Bernard, 2003). Common activities outsourced are out-of-engine chassis repairs, major drive-train repairs, in-chassis engine repairs, and tire repairs.
- Vehicle safety equipment: A number of technologies are now available to enhance vehicle safety performance, including collision avoidance systems, collision warning systems, lane departure warning systems, and advanced onboard sensor systems that monitor system performance. These are covered in more detail in the section on vehicle designs and technology in this circular. The *CTBSSP Synthesis of Safety Practice 1: Effective Commercial Truck and Bus Safety Management Techniques* reported that safety managers value the importance of basic safety features, but otherwise the value of additional systems is not as highly rated, and many managers are not yet convinced about the effectiveness of advanced technologies.

Carrier Self-Evaluation Programs

The *CTBSSP Synthesis of Safety Practice 1: Effective Commercial Truck and Bus Safety Management Techniques* (Knipling, Hickman, and Bergoffen, 2003) presents an overview of several approaches to voluntary carrier self-evaluation programs designed to improve overall safety performance. These can be characterized as certification of fleet management practices, certification of safety managers, and industry-promulgated best practices. The following summarizes these approaches:

- Certification of fleet management practices: The focus here is on third-party evaluation and measurement of fleet safety performance, and, in some cases publication and recognition of the certification process. These approaches include
  - ISO 9000 certification. This is likely the most structured of these processes. While the process does not focus specifically on truck fleet safety management, overall management practices have been found to have an impact on fleet operations (Naveh et al., 2003). A study compared safety results and other performance results of ISO 9000 certified and noncertified motor carrier companies before and after certification. Positive results appeared to flow primarily from the overall ISO 9000 process applicable to all of the carrier firms' management and operational practices. The study authors noted that the main limitation of the data supporting the analysis is that it does not report causation and thus includes the confounding effects of other drivers and vehicles.
  - The Responsible Care Program. This program is promoted by the chemical industry's trade association (American Chemistry Association, 2002) and affiliated

associations as a formal process through which truck and other operations voluntarily participate in audits of activities and practices formally prescribed and published by a unit of the association. The activities are designed to ensure safe handling of hazardous and other toxic materials throughout the life cycle of the products.

- The Canadian Standards Association (CSA) Carrier Safety Management System. This is a voluntary program designed to evaluate and qualify a carrier's safety management system to an established set of requirements based on CSA International's *B619-00 Carrier Safety Management Systems* standard. The standard applies basic management system principles, but from a safety management perspective. To complement this standard, CSA has also designed a qualification program so that safety management efforts can be audited by an independent third party, CSA International.
- Partners in Compliance (PIC). The PIC program in Alberta has been approved as the recognized Canadian carrier safety excellence program by the Canadian Council of Motor Transport Administrators. The PIC program establishes benchmarks and best practices for member carriers and requires reporting and auditing to ensure carriers are meeting the program safety requirements. For the extra effort in meeting the benchmarks, member carriers are provided with limited government benefits meant to partially offset the cost.
- The Surface Deployment and Distribution Command rating process. This program is a supplement to the FMCSA safety rating process and includes a multilevel rating process, more expansive than the FMCSA system. The auditor is Consolidated Safety Services. Although this process has regulatory underpinnings, it provides an additional benchmark for measuring safety performance in a certification context.
- The TruckSafe Accreditation Program. This program has been developed by the Australian Trucking Association as a voluntary business and risk management system aimed at improving the safety and professionalism of trucking operators. The program includes four standards areas: workplace and driver health, vehicle maintenance, driver training, and management. After entry and compliance audits, the participating fleet is eligible for accreditation by the TruckSafe Industry Accreditation Council, which is an independent body. The Australian Trucking Association provides support materials for the program.
- Insurance evaluations. Although these systems are proprietary, various insurance companies and underwriters that support the trucking industry have developed evaluation systems that support the risk-rating and rate-setting processes the companies use in evaluation and insuring carriers. One predictive index of carrier risk based on an aggregation of the safety records of individual drivers in the fleet (e.g., traffic violations, HOS violations) is described in Knipling et al. (2004).

- Certification of managers:
  - The North American Transportation Management Institute has been affiliated with ATA. It offers a number of certification courses for safety managers, including Certified Director of Safety, Certified Safety Supervisor, Certified Director of Maintenance/Equipment, Certified Supervisor of Maintenance/Equipment, and Certified Driver Trainer.
  - The National Private Truck Council's Certified Transportation Professional Program includes a component of safety management in its overall certification of fleet managers as certified transportation professionals.

- Industry-promulgated best practices:
  - ATA has published two studies focused on best practices in the safety management field—the last of which is titled *SafeReturns: A Compendium of Injury Reduction and Safety Management Practices of Award Winning Carriers*. These studies currently provide a foundation for developing elements of a safety management system and process but do not formalize these in a systematic evaluation scheme.
  - The National Private Truck Council has made available to its members a new program, accessed from its website, www.nptc.org, entitled *Best Practices Safety Guide* (NPTC, 2002). The approach uses a tool—Virtual Fleet Risk Manager—that leads the safety manager through a series of questions about a total regime of safety practices. The responses lead the safety managers to a series of follow up actions, and the fleet can benchmark its own performance against other fleets in the NPTC organization.
- Effectiveness of processes and programs: Information on relative effectiveness of safety management recommended practices and safety certification programs are limited. From their efforts to evaluate the ISO 9000 results, Naveh et al. (2003) report that "voluntary ISO 9000 certification does have the potential to alleviate the regulatory burden and improve overall motor carrier safety. However, certification is relatively new in this industry, and companies that have been certified may be unique."

On the effectiveness of *TruckSafe,* the Australian Trucking Association (2002) represents that "the records of the largest insurer of transport equipment indicate that TruckSafe operators have 40% fewer accidents than non-accredited operator, which results in a better deal overall." The association also holds that participation in TruckSafe results in reduced worker compensation costs and reduced maintenance costs.

By definition, the ATA's SafeReturns population of carriers represents those with the best safety records, as those recognized through performance and by their peers as among the safest in the trucking community. However, there is no analytical chain of evidence linked to the practices of this population and their status.

CSA's Carrier Safety Management Systems Program is relatively new. CSA supports its potential effectiveness with evidence of positive safety results in other industries where CSA certification is applicable, and has recently completed two case studies of carriers that implemented a carrier safety management system (CSMS) as prescribed by standard CAN/CSA B619-00.

Case studies (Drew, 2002) indicate that each carrier experienced improvement in quantitative measures obtained from the commercial vehicle operator (CVO) registration data after implementation of the CSMS. The measures relate to driver performance, vehicle condition and convictions and are derived from safety inspections conducted by the Ministry of Transportation. Information on relative improvements in crash rates were not included in the case study summaries.

Safety management recommended practices and certification programs appear to hold significant promise in an overall strategy to improve safety performance of commercial motor carriers. However, the discipline of certification and best practices definition of motor carrier safety systems is in a developmental stage. Even though there common elements and approaches are emerging, there is currently no synthesis effort ongoing to organize information on results and relative effectiveness of alternative strategies and tactics.

RESEARCH NEEDS

Notable research needs relating to improved carrier safety management practices, safety certification, and self-evaluation includes the following:

- Driver training: While driver training is generally recognized as an essential component of a fleet management safety regime, the research community is still seeking a quantified basis to determine the impact of driver training on safety performance (Volpe National Transportation Systems Center, 2003). Additional research is needed to determine the appropriate training regime that can produce statistically significant reductions in CMV driver crashes.
- Incentives and BBS management: Because behavioral safety management has been successful in other industries but not systematically applied in commercial truck and bus transport, an obvious opportunity is to evaluate these methods in a CVO context. A broad-based long-term study of BBS techniques in CMV operations should be undertaken. Additionally, independent analyses of safety placards, as well as outcome-based incentive programs, would be valuable. Additionally, onboard safety measurement technology should be evaluated to determine potential values in enhancing fleet safety management regimes.
- Driver health and wellness: To establish a stronger foundation for a range of driver health and wellness programs now being employed, a quantitative determination of the role that physical and medical conditions play in driver productivity and safety would be valuable. This should include an evaluation of the GIG wellness program that is being used within the industry. (The section on health and wellness of commercial drivers addresses the health and wellness issue in more detail.)
- Carrier self-evaluation measures of effectiveness: There is a need for a common evaluation framework for assessing programs, including common measurement disciplines, and rigorous assessment of evidence for crash-reduction effectiveness.
- Relationship of certification and self-evaluation to regulatory regimes: More information and empirical research are needed on how certification and best practices programs might enhance or supplant a range of regulatory and compliance strategies.

REFERENCES

American Chemistry. *Responsible Care*. 2002. Available at http://americanchemistry.com. Accessed Oct. 1, 2002.

American Trucking Associations Foundation. *SafeReturns.* American Trucking Associations, Alexandria, Va., 1999.

American Trucking Associations Foundation. *Truck Driver Risk Assessment Guide and Effective Countermeasures: Recommended Management Practices*, 1999.

Australian Trucking Association. Improve Your Business with TRUCKSAFE. Available at http://www.trucknbus.com.au/ata. Accessed Oct. 1, 2002.

Corsi, T. M., and R. E. Barnard. *Best Highway Safety Practices: A Survey of the Safest Motor Carriers About Safety Management Practices*. Final report, FMCSA Contract No. DTFH61-98-X-00006. FMCSA, U.S. Department of Transportation, 2003.

Drew, T. *Carrier Safety Management Systems: Case Studies*. CSA International, Mississauga, Ontario, Canada, 2002.

Drew, T. Carrier Safety Management Systems: A Collaborative Approach to Carrier Safety. Presented at International Truck and Bus Safety Research and Policy Symposium, Knoxville, Tenn., April 3–5, 2002.

Knipling, R. R., L. N. Boyle, J. S. Hickman, J. S. York, C. Daecher, E. C. B. Olsen, and T. D. Prailey. *CTBSSP Synthesis of Safety Practice 4: Individual Differences and the High-Risk Commercial Driver*. Transportation Research Board of the National Academies, Washington, D.C., 2004.

Knipling, R. R., J. S. Hickman, and G. Bergoffen. *CTBSSP Synthesis of Safety Practice 1: Effective Commercial Truck and Bus Safety Management Techniques*. Transportation Research Board of the National Academies, Washington, D.C., 2003.

National Private Truck Council. Certified Transportation Professional. Available at http://www.nptc.org. Accessed Oct. 1, 2002.

Naveh, E., A. Marcus, and G. Allen. *ISO 9000's Effects on Accident Reduction in the U.S. Motor Carrier Industry*. Draft Study. Carlson School of Management, ITS Institute, University of Minnesota, Minneapolis, 2003.

North American Transportation Management Institute. Available at http://www.natmi.org. Accessed Oct. 1, 2002.

Stock, D. *I-95 Corridor Coalition Field Operational Test 10: Coordinated Safety Management, Volume I: Best Practices in Motor Carrier Safety Management*. Pennsylvania Transportation Institute, 2001.

Volpe National Transportation Systems Center. *Proposed Rule Regulatory Evaluation: Minimum Training Requirements for Entry-Level Commercial Motor Vehicle Operators*. FMCSA-1997-2199-161. July 2003.

Volpe National Transportation Systems Center. *FMCSA Safety Program Effectiveness Measurement: Intervention Model; Roadside Inspection and Traffic Enforcement Effectiveness Annual Report*. Publication No. FMCSA-RI-04-029. December 2004. Available at http://ai.volpe.dot.gov/CarrierResearchResults/outreach.asp.

Vehicle Design and Technology

DUANE A. PERRIN
ROBERT M. CLARKE
HELMUT E. KNEE
ROBERT KREEB
MICHAEL PEREL
PAUL RAU
ALRIK SVENSON

Improvements in design and technology can influence heavy-vehicle safety in two ways. First, the performance of the vehicle itself can be improved, to make it better at avoiding or surviving crashes, and second, vehicle-based technologies may be employed to help the driver perform better by being more aware of his or her surroundings, physical and mental state and driving performance. Crash statistics show that 85% of fatalities and 78% of injuries in crashes involving large trucks are people outside the truck (*1*). In fatal two-vehicle crashes involving a passenger car and a large truck, 98% of the fatalities are occupants of the passenger vehicle. Primarily for this reason, most research on heavy-truck safety design and technology concentrates on ways to help trucks avoid crashes.

Despite a wealth of research and product development, many new technologies are not purchased in significant numbers by heavy-truck buyers. Effective deployment of advanced safety technologies and hence the realization of their potential safety benefits depend on business, legal, economic, and regulatory factors.

VEHICLE BRAKING, HANDLING, AND STABILITY

Heavy trucks typically take at least twice the distance to stop from highway speeds on dry roads as passenger vehicles. On wet roads, the disparity is even greater. Practical considerations such as tire life, vehicle control, load transfer, suspension design, and physical configuration of the truck preclude making stopping performance equal to that of passenger cars; however, marked improvements can be made. Brake suppliers and heavy-truck manufacturers have demonstrated reduced stopping distances from highway speeds of 30% or more for some configurations of trucks. Achieving these performance improvements requires greater braking torque, particularly at the front (steering) axle. Most high-performance heavy vehicle braking systems utilize air disc brakes or high-performance drum brakes.

Because current air disc brakes are reportedly 2 to 2.5 times the cost (to the customer) of drum brakes, they have achieved limited market penetration. However, they provide several benefits. Drivers can better modulate air disc brakes with a resulting increase in braking stability and performance. The physical design of air disc brakes reduces the susceptibility of the system to fade as heat causes the rotor to expand into the pads as opposed to drum brakes having the drums heat up and expand away from the shoes. This could ultimately result in the drum brakes running out of brake chamber stroke compared to the disc brake's stroke requirement remaining relatively constant. Current air disc brakes realize reduced maintenance through much faster and simpler brake pad changes, with fewer parts and tools required as opposed to drum systems. Air disc brakes also use air more efficiently than drum brake systems, especially during antilock brake system (ABS) modulation, and may allow the adoption of smaller air compressors or a reduction in air compressor maintenance.

The success of the latest generation of air disc brakes has resulted in sales of more than 4,000,000 units in Europe over the past decade. In the United States however, air disc brakes sales are estimated to be less than 70,000 units with a majority of sales going to noncommercial vehicles. U.S. fleet operators remain skeptical about the maintainability, acquisition, and life-cycle costs of air disc brakes. Further research is needed to address these concerns.

Brake manufacturers' tests have shown that in some cases high-performance drum brakes can outperform air disc brakes at the current 60-mph emergency stopping requirements of FMVSS No. 121. These systems feature wider drums, higher friction coefficient brake shoes, more powerful air chambers, and increased brake sizes on the steer axle. A possible disadvantage of larger drum brakes on the steer axle (where they are most needed) is that they are more susceptible to increased shake and vibration of the steering wheel due to the self-energizing characteristics of drum brakes on out of round or out of balance drums.

One technology known to resolve compatibility differences between disc and drum foundation brake technologies is the electronically controlled braking system (ECBS). ECBS is an advanced brake control system technology that controls the brakes electronically rather than pneumatically. In ECBS, an electronic circuit is integrated into the brake treadle valve. By depressing the treadle valve, the driver sends a deceleration command to the microprocessor-based control unit. The control unit responds by sending an electronic control signal to the pressure modulator instructing a set amount of application pressure to a specific brake chamber. The benefits of electronic control include faster control signal speeds, precise regulation of application pressures, and improved brake balancing. Much of the control functionality of an ECBS can be provided at reduced cost by enhanced ABS through the use of ABS modulator and traction control valves. Both ECBS and enhanced ABS provide the platform for technologies such as adaptive cruise control, collision warning, and smart retarders to be integrated with the braking system. ECBS have microprocessor-based control units, pressure control modules, and sensors to enable the implementation of stability and roll control programs. On the basis of real-time sensors that monitor vehicle dynamics (such as speed, acceleration, steering wheel angle, individual wheel speeds, yaw rate, and lateral acceleration) coupled with preprogrammed control algorithms (also called enhanced stability programs or ESP), an ECBS can selectively brake individual wheels to assist in preventing a vehicle rollover or jackknife event. Such a system could be particularly beneficial in controlling rearward amplification and rollovers of multiply-articulated combination-unit vehicles (especially triples) in situations where they are forced to make a rapid lane change. If the system determines that a rollover event is imminent, the system applies the brakes at individual wheels; this decreases the vehicle's speed until the threat subsides.

U.S. DOT has conducted and continues to conduct research on improved brake systems, including ECBS (*2*). NHTSA has conducted extensive track tests at its Vehicle Research and Test Center. In addition, two field operational tests (FOTs) are part of U.S. DOT's Intelligent Vehicle Initiative (IVI). The first FOT, completed in 2004, followed the performance of a fleet of 100 tractors, half with ECBS and half without. Data from that FOT are being analyzed. The tractors were in service for 2 years. The second FOT, now under way, will study the performance of both tractors and trailers with ECBS made by a different manufacturer.

SEEING AND BEING SEEN

Truck headlighting systems must meet the same FMVSS 108 requirements as cars. However, the performance of truck headlighting may differ from cars because of their higher mounting heights. The differential effect due to mounting height is generally well understood in terms of its effect on the ability of truck drivers to see retroreflective and diffuse reflectance objects (*3*,*4*). Increasing mounting height increases the ability of truck drivers to detect pavement markings.

Each year approximately 28,000 crashes involving combination-unit trucks occur when these units are making lane changes, merging, or making right-turn maneuvers. Research is under way at NHTSA that addresses lane change and merge crashes involving heavy trucks by assessing visibility from today's tractors, documenting current mirror design and aiming, and measuring the quality and quantity of field of view. This research will establish the performance requirements for indirect viewing provided by mirror or video systems. Testing will be performed under static and dynamic conditions, whereby heavy vehicle drivers will perform maneuvers required for licensure. These data will provide the basis for federal rules (FMVSS 111) regarding the design of heavy vehicle indirect viewing systems.

NHTSA research led the way to identifying requirements for retroflective markings on trailers to help prevent drivers from crashing into the rear and sides of trucks at night (*5*). Subsequent to the actual installation of conspicuity markings as mandated by FMVSS 108, NHTSA evaluated the effectiveness of the retroreflective tape in reducing crashes (*6*). That study found that overall, the tape reduced side and rear impacts by 29%. In dark-not-lighted conditions, the tape reduced impacts by 41%.

An analysis of rear-end fatal crashes involving trucks by FMCSA indicates that 40% of trucks that were struck by other vehicles had one or more lighting violations, as opposed to only 13% of the trucks that struck other vehicles (*7*). These lighting violations included headlights, taillights, brake lights, signal lights, and marker lights; although the statistic is dramatic, it's not clear exactly what cause and effect may be at play. Although conspicuity aids help reduce nighttime crashes into the rear and sides of trucks, more than 70% of rear-end collisions into trucks occur during daylight. To help address this problem, FMCSA is sponsoring research to identify improvements that could be made to rear lighting and signaling systems. This project is examining crash data and past research to identify potential improvements, such as making lighting systems that are less susceptible to in-use degradation and developing more attention getting signals.

IMPROVING DRIVER AWARENESS

The Eaton Vorad Company has been selling a forward collision warning system (CWS) and a side-object detection system that may help warn drivers of imminent crash situations. Little independent research has been conducted regarding the effectiveness of the side-object detection systems. As part of the IVI, NHTSA evaluated the effectiveness of the forward CWS on a fleet of 100 trucks. Driver responses to the warning alerts were measured and collected to assess the extent to which the drivers adjust their driving after receiving warnings. Forward-looking video on some trucks provided data on near misses as a complement to the rest of the stored parametric data. All of these data will be analyzed to determine the effectiveness of the CWS and driver behavioral changes.

A possible negative effect of introducing new technologies into vehicles is that they may be a source of distraction for the driver. While most of the research and concern about driver distraction has focused on passenger vehicle drivers, CMVs are often the first to adopt new technologies with could impact the drivers' attention to the roadway. To explore the extent to which such technologies may be increasing the safety risk for truck drivers, FMCSA and NHTSA initiated a study to examine the issue (*8*). The investigators examined a sample of truck devices and conducted focus groups with drivers. The researchers found that device manufacturers provide the capability to limit driver use of the systems while driving, but some fleets and drivers do not implement this capability. Most of the drivers and others interviewed do not perceive distraction from in-vehicle devices to be a significant safety problem compared with other issues, such as fatigue. Future research efforts need to quantify objectively the incidence of distraction as a causal factor in crashes. Existing crash databases do not capture the extent of the truck driver distraction problem because of its likely underreporting. The FMCSA–NHTSA Large Truck Causation Database may have some new insights into the distraction problem.

To address the issue of driver distraction from in-vehicle devices, some manufacturers are developing driver–vehicle interface devices that prioritize and present information to the operator. It has been recognized that to take full advantage of such systems, some level of standardization or best practices should be developed so that drivers develop an accurate mental model of how such systems operate and can comfortably move from truck to truck without learning a new system. Research related to CMV operator driver distraction, cognitive processes, and human factors research is ongoing and will help sort out these issues.

When considering all vehicle types, approximately 100,000 crashes per year (1.6% of 6.3 million) are identified on PARs where drowsiness was indicated in a report check box and from "drift-out-of-lane" crashes not specifically indicated but which had drowsiness characteristics. Approximately 1,357 drowsiness-related fatal crashes resulted in 1,544 fatalities (3.6% of all fatal crashes), as reported by FARS. Approximately 71,000 of drowsiness-related crashes involved nonfatal injuries. The role of drowsiness in the leading causes and types of crashes may be largely underestimated because of unreported off-roadway crashes, police inability to verify drowsiness, and driver reporting error.

In previous trucking summit meetings, drowsiness was named as the Number 1 driving problem. The number of annual drowsy driver crashes (95.9%; a total of 96,000 including 1,429 fatalities) involved drivers of passenger vehicles, whereas 3.3% (a total of 3,300 total including 84 fatalities) involved drivers of combination-unit trucks. However, (*a*) drowsiness was cited in 0.82% of truck crash involvements versus 0.52% of passenger vehicle crashes; (*b*) expected involvements for combination-unit trucks is 4.5 times greater than for passenger vehicles because of exposure (60,000 versus 11,000 mi/year), operational life (15 versus 13 years) and night driving; and (*c*) 37% of the truck-related drowsy driver fatalities involved individuals outside the truck, as compared with 12% of the fatalities from drowsy passenger drivers.

Laboratory- and field-based studies have addressed the question of the effectiveness of countermeasures for loss of alertness. In a laboratory experiment using a sleep deprivation protocol, conditions were repeated months later where subjects received alerting stimulation. Results showed that the pattern of lapsing for each subject did not change from subject's earlier nonalerted experience (*9*). Later, a simulator study examined the driving performance of heavy-vehicle drivers who had just completed an 8-h overnight express run. Again, various alerting stimulation were not effective (*10*). Results did show that when drivers were provided objective feedback about their state of alertness, they were able to initiate their own strategies to remain alert with improved lane-keeping performance. Without the objective feedback, drivers underestimate their deteriorating state, whereby alerting strategies are often applied either too late or not at all.

Technology for the unobtrusive detection and monitoring of drowsy driving has been evaluated with regard to the validity of measures against a known medical index of loss of alertness, i.e., PVT. Among numerous other measures and devices examined, the percentage of eyelid closure over the pupil over time (PERCLOS) has shown the greatest correlation with PVT in several validation studies (*11*). As a result, this measure has been implemented in a camera-based system, which is presently the subject of a field operational test for understanding the safety benefit and usability of this device for CMV drivers.

MODIFYING DRIVER BEHAVIOR

The goal of making drivers more aware of potentially dangerous situations often is to cause the driver to change behavior to decrease the likelihood that such a situation will recur. For example, a study by UMTRI found that truck drivers routinely came very close to the rollover threshold of the vehicle when negotiating expressway exit ramps. When drivers were interviewed about this practice, they said they were not aware of how close they were. A system developed by UMTRI under contract to NHTSA provides an in-cab graphical display of what the vehicle is doing relative to the rollover limit. It is not meant actually to prevent rollover but to teach drivers how to associate the limit with a particular feel so they will remain within a safe range. Likewise, research has shown that while drivers know when they are sleepy, they are very poor judges of when they are actually about to fall asleep. One possible use of a drowsy driver–monitoring system would be to provide the driver with knowledge of how often or how long he or she was getting into a dangerous situation, with the intention of causing a change of behavior or even a change of lifestyle that would result in fewer such episodes.

Using advanced in-vehicle driver performance monitoring devices to provide feedback to drivers that they can use to improve their safety-related behaviors is a promising concept to consider in a fleet safety program. The benefits may come from drivers behaving more cautiously just knowing that their performance is being monitored or from drivers learning how to reduce risky driving behaviors, such as tailgating. Wouters and Bos (*12*) found that the use of driver monitoring with vehicle data recorders in commercial fleets in Belgium and the Netherlands helped to reduce crashes by 20%. A FMCSA tech brief (*13*) discusses the successful applications of worker feedback in industrial settings and how that approach might be applied in the trucking industry. Basically, the approach uses in-vehicle technology to monitor driver behavior and provide feedback to improve unsafe behaviors.

The abovementioned report also discusses the concern that this technology could be criticized as intruding on driver privacy. Some fleets are using onboard devices to monitor speed and HOS, for instance. Technology exists to monitor and record essentially everything that goes on in a vehicle. A study by Roetting et al. (*14*) conducted focus groups to discuss the most acceptable way to implement a BBS program in trucking fleets. The results showed that drivers would accept feedback from in-vehicle technology if it is designed and implemented appropriately. However, very little research has been conducted to determine how much observation would be considered appropriate.

In addition to intentional driver behavior modification, we know that drivers tend to adapt to new technologies by learning to take advantage of increased vehicle performance afforded by vehicle changes. This driver adaptation does not always take the form that was intended or anticipated when the technology was introduced. In passenger cars at least, it has been shown that some drivers compensate for improved vehicle performance by driving more aggressively. These unintended consequences can decrease the expected benefits of the vehicle improvement. Whether and to what extent this phenomenon exists with regard to heavy-vehicle technologies has not been ascertained. This is an area where there is a need for more research, because this area of human behavior is not well understood or quantified.

ONBOARD CONDITION AND PERFORMANCE MONITORING

With the advent of electronically controlled engines in the early 1990s, heavy-duty truck manufacturers have been capable of recording various operating parameters utilizing available memory in the same electronic control units (ECUs) that are necessary for engine and powertrain control. Initially, manufacturers selectively utilized this capability to record conditions that would help with warranty concerns such as “over rev” or “overheat” conditions. This notion of recording vehicle operating data has been expanded greatly since that time, with truck original equipment manufacturers as well as aftermarket suppliers offering a variety of onboard data recording systems and functionality. These systems are commonly referred to as vehicle data recorders (VDRs) or event data recorders (EDRs).

By observing and analyzing vehicle performance parameters, driver inputs, and vehicle responses, manufacturers as well as operators of commercial trucks have at their disposal a wealth of new information to help them learn from vehicle events. The information gathered provides new opportunities for improving vehicle reliability, profitability, and safety. For example, monitoring operating conditions (such as brake applications) might be used to tailor routine maintenance, while monitoring vehicle health (such as fault codes) could help prevent unscheduled out-of-service events and assist with problem diagnostics. Monitoring driver performance (speed, hard-braking activity, gear-shift selection, etc.) might help with driver training as well as improve fuel economy. Moreover, VDRs could be used to record a variety of operating data surrounding predefined triggered events (including a crash event) in order to help understand and reconstruct the conditions that led to the event.

Today’s VDRs can record data from multiple sources onboard the vehicle, including engine data, brake–accelerator petal inputs, multiaxis accelerometers, ABS and wheel speed data, and even GPS location. The data can then be displayed to the driver or extracted at an operating or maintenance facility.

Heavy-duty engine manufacturers Cummins, Detroit Diesel, Caterpillar, and Mack offer VDRs that display diagnostic information to the driver and make trip summary and diagnostic data available for download via the J1587 network. Furthermore, Mack offers short-range wireless capability to download this data from the vehicle to a maintenance or distribution terminal via WiFi connection. Numerous aftermarket VDRs are also available for onboard monitoring and reporting of diagnostic, accident, or video data. A representative aftermarket VDR is the Tacholink Millennium (*15*), which records trip summary data along with accident data and GPS location. Many asset management and vehicle-tracking systems also record and transmit diagnostic data over long-range satellite or cellular communication. Manufacturers of these systems include Qualcomm, Tripmaster, XATA, and Terion.

VDRs have seen growth in niche markets, where safety and security are paramount, but mainstream adoption of the technology has not taken place. One major manufacturer offered a very capable VDR that could also record accident data, but recently took it off the market for lack of sales. Perhaps the most widespread adoption has been that of asset management tracking systems. Fleets have found that the benefits of asset–vehicle tracking, coupled with improved vehicle diagnostics, provide the necessary return on investment. For example, Qualcomm has more than 325,000 asset tracking systems operating on heavy-duty vehicles in more than 2,500 North American fleets and has 465,000 systems operating worldwide.

The maturity of VDRs will be accelerated by the development of heavy-duty onboard diagnostic (HD-ODB) standards for heavy-duty vehicles. OBD standards were developed as a method for monitoring emissions-related components and have been required for light-duty vehicles since 1988. Current Environmental Protection Agency plans are to implement a similar system on heavy-duty vehicles by 2007. The HD-OBD will lay the groundwork for a generalized process for storing and extracting onboard data (and although the data will be emissions-related, the process could be leveraged for safety-related data as well). This will likely help solidify the design parameters associated with a VDR and lead to synergies between HD-OBD and VDR components.

The use of VDRs to record accident event data, often termed EDRs, and assist in accident reconstruction is of particular interest to local, state, and federal governments. Research into EDRs is ongoing by both government and industry. NHTSA conducted two working groups related to EDRs focused on (*a*) light-duty vehicles (*16*) and (*b*) trucks, motor coaches, and school buses (*17*). These working groups included representatives from industry, universities, researchers, and federal–state–local governments. The focus was on determining when data should be collected, what data elements should be collected, and the survivability of the data. The NHTSA EDR working group's findings included a list of core (Priority 1) and supplemental (Priority 2) data elements for heavy-duty vehicles.

Also, FMCSA has tasked a contractor with developing requirements and functional specifications for event data recorders specifically for heavy-duty vehicles. The study is focused on determining the most appropriate data elements to collect, an analysis of operational–survivability concerns, and a review of data ownership concerns. The report is expected to be published in the near future.

Challenges still remain in quantifying the benefits these systems in terms of their impact on improving reliability, profitability, and safety. The life-cycle costs of such systems are also an important factor that fleets continue to struggle with. FMCSA is engaged in a study to better understand the capital and operating costs associated with various types of VDRs and EDRs, and to quantify benefits for differing categories of end users. A final report is expected in the near future.

LONGER-TERM TECHNOLOGIES

There are a variety of advanced, longer-term technologies likely to impact heavy-duty vehicle design, safety, and operation. Among these are advanced deployment of "by-wire" systems, "smart copilots," and dedicated short-range communications (DSRC).

It is likely that future trucks will see increased use of driver-assistance aids that take active control of the vehicle in various situations. Freightliner's rollover stability feature recently tested under U.S. DOT heavy-duty IVI program is such an example (*18*). The ability to take active control of the vehicle will be linked to the development and increased use of so-called by-wire subsystems. Such systems replace traditional mechanical, air, or hydraulic control with electronic control using components such as electric servo-motors, solenoids, and actuators, combined with a microprocessor unit that controls these devices via preprogrammed algorithms. Operator input is typically via a potentiometer-based device that mimics the traditional input device. Once an electronic interface is available, active control of the system is possible. The throttle control has long been converted to by-wire operation and electronic-controlled brakes are also under test and development. Suspension and steering systems are also candidates for at least partial by-wire operation that would allow for tailoring the response of these systems based on input from various sensors (in addition to input from the driver). Even tire pressures can be actively controlled to help improve vehicle stability or reduce wear. Dynamic suspension systems are already widely available on light-duty vehicles. If suspension response could be actively controlled on heavy-duty vehicles, this might be yet another variable that vehicle engineers could use as part of an antirollover or stability enhancement program. Fast-response, dynamic control of heavy-duty suspensions, however, present major challenges compared with light-duty suspensions, and only limited activity in this area is taking place at this time. As by-wire systems proliferate, research will be needed to determine if, how, and to what degree automatic control of various vehicle subsystems should occur to maximize safety.

Since 1998, ASTM and IEEE, with the support of ITS America and U.S. DOT, have been working on developing wireless communications standards to support vehicle-to-vehicle and vehicle-to-infrastructure communications. The standards are roughly based on the now commonplace 802.11, or Wi-Fi standards but have been modified for vehicular use. The standards focus on a 5.9Ghz communications architecture (communications band) that was recently approved by the Federal Communications Commission (FCC) (*19*) for exclusive use for vehicular applications—with a priority given for communications that support safety-related applications. Examples of applications that might be leveraged by CMVs are shown in Table 1.

TABLE 1 Examples of Applications that Might Be Leveraged by CMVs

Public Safety Applications	Private Sector Applications
Vehicle-to-Vehicle Approaching emergency vehicle (warning) Cooperative collision warning Cooperative adaptive cruise control	**All Vehicles** Access control Onboard diagnostic data Repair-service record Vehicle ECU program updates Enhanced route planning and guidance
Vehicle-to-Infrastructure Road condition warning Low bridge warning Work zone warning Toll collection Traffic information Green light—optimal speed advisory	**CMVs** Automated vehicle safety inspections Border clearance information (credentialing) Electronic manifests (hazmat) Unique CVO fleet management applications

Clearly, there will be substantial research needed to refine the concepts of operation for each of these applications, to develop prototypes and simulation models, and, finally, to test and demonstrate the concepts and applications with real vehicles (*20*).

TRUCK SIZES AND WEIGHTS

Trucks now routinely approach 40% of the traffic mix on certain segments of Interstate highways at various times of day, with overall traffic densities frequently approaching or exceeding maximum free-flow capacity limits. The truck portion of the traffic mix will likely continue to increase. Simultaneously, truck accidents and related fatalities are rising, as is public concern about this trend. Against this backdrop, there will be continuing strong political debate and economic pressure to increase maximum allowable truck size and weight limits as a way of handling both the need for productivity improvements and to minimize the sheer number of trucks on the road.

In recent years there have been a significant increase and improvement in the body of objective information upon which any decision to address this issue might be based, as more and higher-quality technical and public policy research has become available. For example, the effects of and costs attributable to individual axle weights and arrangements and to overall weight and vehicle configurations on bridges have been more clearly identified. Also, methodologies for assessing the effects of various vehicle designs, configurations and axle arrangements, and weight and cargo loadings on vehicle dynamic handling and stability performance and, in turn, safety, have been developed. This creates the possibility that objective performance-based evaluation methodologies and acceptability criteria could be developed relative to these issues. This, in turn, could lead to the opportunity to develop responsible, reasonable, balanced trade-offs.

TRB Special Report 267: Regulation of Weights, Lengths, and Widths of Commercial Motor Vehicles, published in 2002, deals with all these issues. It concluded that regulatory analyses of the benefits and costs of changes in truck dimensions are hampered by a lack of information. Regulatory decisions on such matters will always entail a large degree of risk and uncertainty, but the degree of uncertainty surrounding truck issues is unusually high and unnecessary. The report concluded that the uncertainty could be alleviated if procedures were established for carrying out a program of basic and applied research, and if evaluation and monitoring were permanent components of the administration of trucking regulations. The study is an excellent basis for moving forward on this difficult but extremely relevant issue.

SURVIVING THE COLLISION

About 700 occupants of large trucks are killed in crashes each year. Of these, about two thirds are killed in rollover crashes. Nearly all of those are ejected from the truck, and nearly all of those who are ejected are unbelted.

There is essentially unanimous agreement among truck safety studies about the qualitative benefits of using safety belts (*21–24*). Safety belts provide protection against multiple injury mechanisms. These include ejection, interior impacts, and maintenance of survival space. Studies have shown that the use of safety belts reduces the incidence of ejection in truck crashes involving some level of occupant injury to virtually zero (<1%) versus observed ejection rates of approximately 10% for unbelted occupants. Among unrestrained drivers in severe crashes (those causing K or A injuries), almost 23% were ejected, while for restrained drivers, only 0.1% suffered complete ejection and 3.3% were partially ejected (*25*). Safety belts also prevent or reduce the severity of interior impacts and provide protection by ensuring that the occupant is held in the space designed to be uncompromised by intrusion in crashes involving crush of cab structure.

The use of front air bags in combination with safety belts can provide benefits in reducing injury to truck drivers, extending protection beyond the use of safety belts alone. From an analysis by UMTRI, it was shown through simulation of impacts that the primary benefit of the air bag in the truck was to provide a further layer of protection by reducing the contact force between the steering wheel and the driver's torso (*26*). Kubaik presented a detailed dynamic testing-based analysis of the effectiveness of a three-point safety belt coupled with an air bag in heavy trucks (*27*). The conclusions of this study were that simultaneous use of both a safety belt and air bag limited the occupant's forward excursion and reduced the occupant injury level to a minimum, while an air bag alone only protected the head and the upper torso. Using an air bag without a safety belt also allowed for greater forward chest and lower extremities displacement, resulting in high femur loads (*28*).

Side air bags show promise in addressing the injury problems associated with ejection and rollover. European crashworthiness studies have explored the use of side air bags to enhance ejection prevention (*29*). In addition to safety belts, the application of side airbag restraint systems is an extremely effective countermeasure against ejection and rollover.

Inflatable tubular structures deploy across the occupant's door window, protecting the occupant from dangerous surfaces and cushioning the head and neck. This reduces movement during a crash, decreases the chance for head contact with the cab roof, and increases the survival space. These air bags in trucks remain inflated for approximately 10 s to accommodate longer incident durations. Although side air bags have the potential to reduce many heavy-vehicle occupant injuries, they are just now beginning to emerge for the heavy-truck market.

Occupant ejection through the windshield is fairly common in crashes involving ejection, according to recent studies (*30*, *31*). Although better windshield retention has been addressed in a few studies, most conclude that restraint technologies such as safety belts and air bags provide a much greater benefit to the prevention of injury for the truck occupant.

Retention of the occupant in the truck cab can be effectively enhanced if the cab provides sufficient survival space and crash force absorption to mitigate the effects of the crash. Detailed statistics on truck occupants who are severely or fatally injured by entrapment and crush in the cab are not readily available. However, some studies have addressed the problem of cab crush through examination of selected samples of truck crashes. A study by Berg in1997 indicated that entrapment occurred in approximately 36% of a set of truck crashes that were studied in detail (*32*). An earlier study by Seiff indicated that entrapment is involved in 22% of fatal truck crashes (*33*).

Cab crush occurs in two principal crash types: rollover and frontal crash into fixed objects or other heavy vehicles. Crash data analysis presented in a NHTSA study conducted by UMTRI showed that rollover was the most common event in severe (causing fatal injury) heavy truck crashes, occurring approximately 63.1% of the time, either singly or in combination with other crash events (*34*).

The issues of rollover crashworthiness of heavy trucks and the design of appropriate roll prevention and protection devices for these vehicles were examined by UMTRI and presented by Winkler et al. (*35*). The vehicle models used in the study were based on the TruckSim truck dynamics simulation package, developed at UMTRI. Simulations of a selected set of vehicles were developed to study their dynamics when subjected to maneuvers that caused them to undergo rollover.

In the 1990s, the industry addressed the truck occupant protection issue under the auspices of the Crashworthiness Task Force of the SAE Truck Occupant Protection Committee. That group spearheaded an SAE cooperative research project (CRP) that developed a series of SAE recommended practices (SAE J2418–J2426), which detail heavy-truck cab-testing procedures. The test procedures were based on heavy-truck accidents in which a truck occupant fatality occurred. The underlying research work that was the basis for those RPs is described in a three-volume set of reports from the Heavy Truck Crashworthiness Cooperative Research Project (CRP-9, CRP-12 and CRP-13), which are available through SAE. The first volume (CRP-9) is the accident investigation work. The other two deal with a finite element evaluation of a truck cab in a rollover simulation (CRP-12) and the development of the recommended practices (CRP-13).

PROTECTING OTHERS

A study of fatal crashes between large trucks and cars by the Insurance Institute for Highway Safety estimated that front, rear, or side underride occurred in half of these crashes (*36*). A federal rule to upgrade the rear impact guard standard for new trailers took effect in January 1998. Underride in frontal collisions continues to be a major problem.

Overall, a collision of a light vehicle with a truck is more than twice as likely to produce a K or an A injury in the light vehicle than a collision with another light vehicle. The aggressivity of trucks is caused by their greater mass, the geometric mismatch between trucks and light-vehicle structures, and greater stiffness of trucks in comparison with light vehicles (*37*). Some general concepts as possible countermeasures have been proposed by UMTRI to improve the crash outcomes for light-vehicle occupants in collisions with heavy trucks (*38*). These are front underride prevention, a crash-attenuating truck front structure, a deflecting front structure, and a layered application of these countermeasures.

From the analysis of crash data, observation of crash damage, and collision and injury modeling analysis, when the impacting light vehicle underrides the front of the truck, the injuries to its occupants are likely to be severe, with a high probability of fatality. Further, the largest number of fatal crashes results from collisions with the front of the truck. The prevention of front underride may be accomplished either through changes in the truck frontal structure to ensure that these structural members are low enough to engage the crash-absorbing mechanism of the light vehicle or through the use of properly designed underride guards added to the existing truck structure. The analysis in the UMTRI study showed that a reduction of 27% to 37% in fatalities could be possible through prevention of front underride (*39*).

Once frontal underride is prevented, crash outcomes can be improved through proper management and dissipation of the collision energy. There are several examples of innovative truck structures that can perform such an energy dissipating function. These include front underride guards that are designed to deflect and absorb collision energy, truck fronts built of collapsible structural members, and an add-on (mounted on existing truck structure) crash attenuator. With more radical changes in truck design (changes in position of the truck engine, cab and associated structural members), it may be possible to achieve crush distances of as much as 12 ft, and it is estimated that a 25% to 50% reduction in fatalities can be achieved (*40*).

Another method of managing the collision energy is to deflect the impacting vehicle through the use of an appropriately designed truck structure. This produces large reductions in the collision energy absorbed by the light vehicle and greatly improves (46% to 72% fatality reduction) the resulting injury outcomes. The greatest drawback of this countermeasure is the possibility of secondary collisions, and further analysis of this aspect must be undertaken before adoption (*41*). Several distinct countermeasures could be used simultaneously in a layered system of aggressivity reduction to provide greater improvements in crash outcomes (*42*).

According to the National Center for Statistics and Analysis, in 2001 there were 438 fatalities and an estimated 3,000 injuries to nonvehicle occupants (this includes pedalcyclists) in crashes involving a large truck. The majority of these are pedestrians. As for fatalities, this number represents approximately 2% of the total number of fatalities in large-truck crashes (*43*). As part of intelligent vehicle systems, CWSs that include pedestrian detection and warning and back-up warning systems have been proposed. These could be applied to heavy vehicles in order to prevent collisions with pedestrians. However, little research to date has been done for heavy vehicles in this area.

TECHNOLOGY DEPLOYMENT

There are significant differences between the way light-duty passenger and medium- to heavy-duty CMVs are produced and sold that have profound effects on efforts to introduce new technologies into these vehicle populations. First and most important are the sheer size and the resulting economies of scale, or conversely, the lack thereof, which exist in the two markets. Approximately 17 million light-duty passenger vehicles are sold in the United States every year, compared with approximately 0.5 million medium- to heavy-duty vehicles (GVWR >10,000 lb). For Class 8 vehicles (GVWR >33,000 lb), the vehicle population that is the focus of most CMV safety efforts, the corresponding figure is only about 175,000 produced each year. Unless there are parallel applications in the light-duty market near total market penetration is necessary for any new technology in order to achieve sufficient volumes to ensure the economic viability of the product given the comparatively small size of the commercial market. While there are examples of successful niche marketing of products, it is extremely difficult to obtain sufficient market penetration—especially of purely safety-related products—unless there is nearly universal market recognition and acceptance of the need and the value of a given technology.

CMVs are not consumer products as automobiles are but are considered capital equipment used by businesses to perform business functions. Because they are bought for a specific business application, buyers demand that manufacturers enable them to highly tailor the designs of the vehicles that they purchase in order to obtain the specific performance and functionality they need. Often, the drivers of CMVs are not the same as their buyers. In these cases, there is great emphasis on economics. Buyers are very cost conscious and tend not to specify equipment or technologies that they do not perceive will yield direct and immediate economic benefit to them. Thus, unlike light-duty vehicles, for which manufacturers can push advanced technologies into the market, particularly on higher-priced luxury models, CMV buyers need to be convinced ahead of time that the cost, functionality, and performance of new technology will yield measurable benefits before they will opt to purchase it.

An added complication for safety technologies is that the beneficiaries of heavy-truck safety are primarily other drivers, not the owners or drivers of the trucks. In a highly competitive business atmosphere, truck buyers are not easily motivated to purchase new technologies solely for the public good. Added equipment must also contribute to their company's profitability in some way and thereby enable them to compete with other companies that have not purchased the same technologies. For this reason, many new safety technologies that are developed and demonstrated are very slow to be deployed. Those safety devices that do gain widespread acceptance generally have secondary–ancillary functions or capabilities that offer a short-term payback to the buyer.

Given these realities, the federal government plays an important role in the process of introducing new safety technologies into the commercial market. Large demonstration programs, involving broad involvement of all the suppliers of a given technology and all the medium- to heavy-truck manufacturers are essential to creating both a sufficient body of data and evidence that a product or technology performs well, in addition to a sense within the industry that the product will be cost-effective and, therefore, worth buying. It is a difficult task to create this critical mass and one that often only the government can accomplish.

In some cases, regulation may be the only way to achieve significant deployment. Even when there is a general consensus that the total benefits of introduction of a new safety technology would outweigh the total costs, there is still the problem of convincing individual vehicle buyers to pay for societal benefits. A regulatory requirement would level the playing field by requiring all companies to buy the equipment and thus eliminate the competitive financial disparity. Regulations are always controversial. It is extremely difficult to quantify the benefits of a technology before the fact. Also, when new technologies are introduced, current buyers pay for future benefits. Finally, there is the issue of individual privacy versus public benefit. For example, more extensive driver monitoring may be beneficial to society in general but may intrude on individual drivers' privacy rights.

SUMMARY

The basic technologies now exist to create trucks and buses that can continuously measure and react to their environment, surrounding traffic, and driver status and actions. Technologies can make these vehicles perform better in response to drivers' commands, keep drivers alert and better informed of possible safety threats, and even take actions independent of drivers. Onboard monitoring of virtually everything in, on, and around the vehicle is possible, and this information can be transmitted anywhere in the world. While research to refine these basic vehicle technologies is certainly necessary, the biggest challenges for the future appear to be in addressing concerns such as benefits, costs, and privacy issues. Even when the overall benefits to society clearly outweigh the costs, implementation of new technologies is often extremely slow, because those who have to pay for the equipment are typically trucking companies but the beneficiaries are predominantly passenger car drivers. Furthermore, costs are often imparted today for benefits that will be realized only at some future date.

NOTES

1. *Traffic Safety Facts—2003 Data*. DOT HS 809 763. National Center for Statistics and Analysis, U.S. Department of Transportation, 2003.
2. www.its.dot.gov/JPODOCS/REPTS_TE/13832.html. SAE's Cooperative Research Program conducted a test of ECBS-equipped vehicles titled Electronically Controlled Braking Systems Performance Evaluation.
3. Rumar, K., M. Sivak, E. C. Traube, and T. Miyokawa. *Nighttime Visibility of Retroreflective Pavement Markings from Trucks Versus Cars*. UMTRI 99-34. University of Michigan Transportation Research Institute, Ann Arbor.
4. Finley, M., P. Carlson, N. Trout, and D. Jasek. *Effects of Vehicle Type on the Nighttime Visibility of Signs and Pavement Markings*. TTI Report 4269-1. Texas Transportation Institute, Texas A&M University.
5. Olsen, P. L., et al. *Performance Requirements for Large Truck Conspicuity Enhancements*. Report No DOT HS 807 815. NHTSA, U.S. Department of Transportation, 1992.
6. Morgan, C. *The Effectiveness of Retro-Reflective Tape on Heavy Trailers*. Report DOT HS 809 222. NHTSA, U.S. Department of Transportation, 2001.
7. http://www.fmcsa.dot.gov/safetyprogs/research/briefs/rear.pdf.
8. Llaneras, E., J. Singer, and R. Bowers-Carnahan. *Assessment of Truck Driver Distraction Problem and Research Needs*, 2004.
9. Dinges, D., et al. *Evaluation of Techniques for Ocular Measurement as an Index of Fatigue and the Basis for Alertness Management*. DOT HS 808 762. U.S. Department of Transportation, April 1998.
10. Mallis, M., et al. *Biobehavioral Responses to Drowsy Driving Alarms and Alerting Stimuli*. DOT HS 809 202. U.S. Department of Transportation, 2000.
11. Dinges, D., et al. *Evaluation of Techniques for Ocular Measurement as an Index of Fatigue and the Basis for Alertness Management*. DOT HS 808 762. U.S. Department of Transportation, April 1998.
12. Wouters, P. I., and J. M. Bos. Traffic Accident Reduction by Monitoring Driver Behavior with In-Car Data Recorders. *Accident Analysis and Prevention*, Vol. 32, 2000, pp. 643–650.
13. The Potential Application of Behavior Based Safety in the Trucking Industry. FMCSA, U.S. Department of Transportation. Available at www.fmcsa.dot.gov/pdfs/tb00-009.pdf.
14. Roetting, M., Y. Huang, J. R. McDevitt, and D. Melton. When Technology Tells You How You Drive—Truck Drivers' Attitudes Towards Feedback by Technology. *Transportation Research*, Part F 2003, pp. 275–287.
15. Bowmonk, Ltd., England. Available at www.bowmonk.com.
16. *Event Data Recorders: Summary of Findings*. Final report. NHTSA-1999-5218. NHTSA EDR Working Group, U.S. Department of Transportation, August 2001.
17. *Event Data Recorders: Summary of Findings*, *Final Report, Vol. II: Supplemental Findings for Trucks, Motorcoaches, and School Buses*. NHTSA-2000-7699. NHTSA EDR Working Group, U.S. Department of Transportation, May 2002.
18. *Evaluation of the Freightliner IVI Field Operational Test*. Final report, May 2003.
19. See FCC Docket No. 01-90, released February 10, 2004.
20. For more information see the following DSRC websites: www.leearmstrong.com/DSRC/DSRCHomeset.htm or http://grouper.ieee.org/groups/scc32/dsrc/index.html.
21. Kubaik, M. Heavy Truck Safety System Performance. SAE 973219. Presented at International Truck and Bus Meeting and Exposition, 1997.
22. Simon, M. C. The Potential Gain to Be Achieved by Generalization of Seat Belts and Air Bags in Trucks. DOT HS 809 220. Presented at 17th International Conference on Enhanced Safety of Vehicles, 2001.
23. Seiff, H. Status Report on Large Truck Safety in the United States. SAE 892541. Presented at Truck and Bus Meeting and Exposition, 1989.

24. Horii, M. Seat Belt Effectiveness for Heavy Truck Occupants During a Collision. Presented at 11th International Conference on Experimental Safety Vehicles, 1987.
25. Krishnaswami, V., and D. Blower. *Heavy Truck Occupant Protection Feasibility*. Final report for Contract DTNH22-00-C-07007. NHTSA, U.S. Department of Transportation,2003.
26. Ibid.
27. Kubaik, M. 1997.
28. Ibid.
29. Simon, M. C. 2001.
30. Neilson, I. European Review of Heavy Goods Vehicle Safety. Presented at 11th International Conference on Experimental Safety Vehicles, 1987.
31. Seiff, H. Heavy Truck Safety—What We Know. Presented at Government/Industry Meeting and Exposition, SAE 851191, 1985.
32. Berg, A. F. Improving the Safety of Commercial Vehicles on the Basis of Entirety Observations with Crash Analysis and Crash Tests. Presented at 15th International Technical Conference on Enhanced Safety of Vehicles, SAE 976174, 1997.
33. Seiff, H. Heavy Truck Safety—What We Know. Presented at Government/IndustryMeeting and Exposition, SAE 851191, 1985.
34. Krishnaswami, V., and D. Blower. *Heavy Truck Occupant Protection Feasibility*. Final report for Contract DTNH22-00-C-07007. NHTSA, U.S. Department of Transportation, 2003.
35. Winkler, C., S. Bogard, and J. Zhou. *The Dynamics of Tank–Vehicle Rollover and the Implications for Rollover—Protection Devices*. UMTRI Report No. 98-53. University of Michigan Transportation Research Institute, Ann Arbor, 1998.
36. Braver, E. R., M. X. Cammisa, A. K. Lund, N. Early, E. L. Mitter, and M. R. Powell. Incidence of Large Truck–Passenger Vehicle Underride Crashes in the Fatal Accident Reporting System and the National Accident Sampling System. *Transportation Research Record 1595*, TRB, National Research Council, Washington, D.C., 1997, pp. 27–33.
37. Clarke, R. M. U.S. Efforts to Improve Heavy Truck Occupant Crash Protection and Reduce Aggressivity in Frontal Truck/Car Collisions. Presented at 14th International Technical Conference on Enhanced Safety of Vehicles, SAE 946189, 1994.
38. Krishnaswami, V., D. Blower, L. Schneider, and D. Putcha. *Heavy Truck Aggressivity Reduction: Statistics, Analysis, and Countermeasures*. Final report for Contract DTNH22-00-C-07007. NHTSA, U.S. Department of Transportation, 2002.
39. Ibid.
40. Ibid.
41. Ibid.
42. Ibid.
43. Traffic Safety Facts, 2002: Large Trucks. DOT HS 809 472. NHTSA, U.S. Department of Transportation, 2002.

Compatibility of Trucks and Buses with the Roadway Environment

Michele Ann McMurtry
Ronald R. Knipling
Douglas W. Harwood

Trucks and buses are a growing segment of the traffic on the nation's highways. According to FMCSA (2004), from 1982 to 2002 there was a 42% increase in registered large trucks and a 93% increase in the miles traveled by large trucks. Many facilities carry 30% to 40% commercial traffic. Any discussion of truck and bus safety would be incomplete without a discussion of the compatibility of trucks and buses with the roadway environment. Although the operating characteristics of trucks may be more critical, traditionally highways were designed for passenger cars with minimum attention to the limitations of trucks. A 1989 FHWA study (Harwood and Mason, 1990) stated "many highway design and traffic operational criteria are based in part on vehicle characteristics. Most of these criteria are based on automobile characteristics, even though truck characteristics may be more critical."

For example, a decade ago, NTSB investigated a propane truck collision with a bridge column and fire on Interstate 287 in White Plains, New York (NTSB, 1995). In this 1994 accident, a cargo tank driven by a fatigued truck driver drifted across the left lane onto the left shoulder and struck the guardrail; the tank hit a column of an overpass. The tractor and semitrailer separated, and the front head of the tank fractured and released propane, which vaporized into gas. The resulting vapor cloud expanded until it found an ignition source and ignited. The tank was propelled about 300 ft and landed on a frame house, engulfing it in flames. The driver was killed, 23 people were injured, and an area with a radius of approximately 400 ft was engulfed by fire. Figure 1 shows an aerial view of the accident site.

NTSB found that when the truck left the traveled way onto the negatively sloped shoulder and foreslope, its rollover speed was considerably reduced. NTSB concluded that the truck exceeded its minimum rollover speed when it left the travel way, at which point the vehicle lost stability and the driver was unable to recover. NTSB also found that each design feature the truck encountered, the pavement drop (3.5 in.), the slope of the ditch (–0.125 to –0.169), and the location of the guardrail met the minimum AASHTO design standards in *A Policy on Geometric Design of Highways and Streets* and in the 1988 *Roadside Design Guide*. Further, NTSB found that each design feature by itself probably would not have created instability problems for the truck, but encountered together, they created a condition from which the driver could not recover. Because a passenger car has a much lower center of gravity and thus a higher rollover threshold, it probably could have negotiated these design features without stability problems, but this truck, with its higher center of gravity and lower rollover threshold, could not.

NTSB concluded that the minimum AASHTO guidelines for the geometric design of highways are not always satisfactory for heavy trucks, especially those with high centers of gravity. As a result of its investigation of the White Plains accident, NTSB recommended that FHWA require that highway geometric design and traffic operations of the National Highway System be based on heavy-truck operating characteristics.

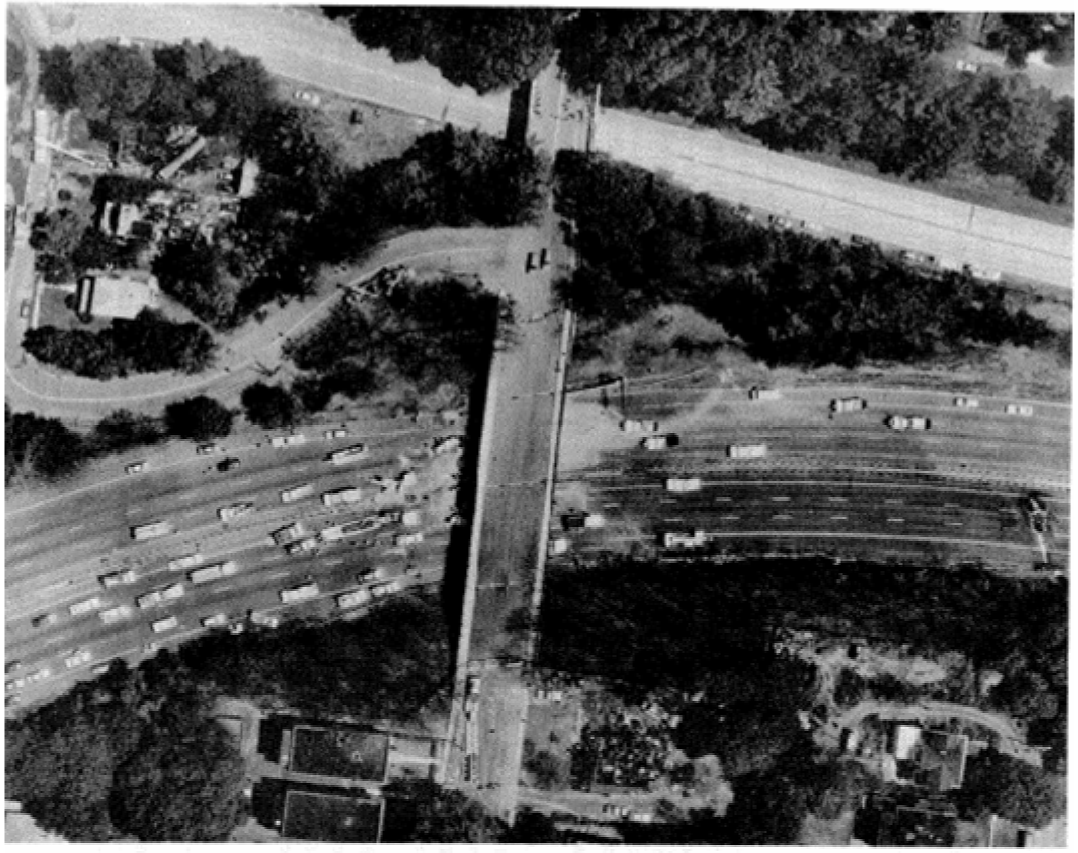

FIGURE 1 White Plains, New York, cargo tank accident. (Source: NTSB)

REVIEW OF RECENT RESEARCH

A primer for those interested in the interaction of trucks and highways is *CTBSSP Synthesis of Safety Practice 3: Highway–Heavy Vehicle Interaction* (Harwood, Potts, Torbic, and Glauz, 2003) This document discusses the various physical and performance characteristics of heavy vehicles that interact with highways including vehicle configurations, size and weight, turning radius, offtracking and swept path width, trailer swingout, braking distance, driver eye height, truck acceleration characteristics, rearward amplification, suspension characteristics, load transfer ratio, and rollover threshold. Highway design features that are based on vehicle characteristics include sight distance, upgrades, downgrades, acceleration lanes, horizontal curves, intersection design, interchange ramps, and roadside features. Traffic control devices, traffic regulations, and ITS initiatives are tools that can be used by highway agencies to accommodate trucks better at locations where safety problems are identified.

The most comprehensive body of work to date relative to the compatibility of truck operating characteristics and roadway design is *NCHRP Report 505: Review of Truck Characteristics as Factors in Roadway Design* (Harwood, Torbic, Richard, Glauz, and Elefteriadou, 2003). Using the range of dimensions and performance characteristics of trucks currently in use, the research team evaluated the adequacy of current geometric design policy and the report made recommendations for a number of changes to the AASHTO's *Policy of Geometric Design of Highways and Streets* (Green Book) Several updates to the design vehicles were recommended including dropping some vehicles no longer in use, adding new vehicles including the Rocky Mountain double and changes to the kingpin-to-center-of-rear tandem distance of one design vehicle. The research also developed a new method of determining the critical length of grade for trucks on long, steep upgrades. The report also recommended that the Green Book provide additional guidance on the maximum entry speeds and the diameter of the inscribed circle for roundabouts and on swept paths of specific design vehicles for the design of double and triple left-turn lanes.

SPECIFIC PROBLEM AREAS

Among the most salient roadway design and operations issues relating to large-truck and bus safety are curves, exit ramps, speed, intersections lane merges, and work zones. In addition, a recently completed instrumented vehicle study (*1*) of long-haul commercial driving (Knipling et al., 2005) found that roadway locations such as undivided highways, entrance–exit ramps, and intersections were associated with greatly increased risk for commercial vehicles. These issues are discussed below.

Curves and Exit Ramps

Excessive speed on curves, or speed beyond the design speed of the curve, is a major cause of vehicle loss-of-control and rollover. Because of their high centers of gravity, heavy vehicles are more vulnerable to rollovers on horizontal curves and curved exit ramps than are smaller vehicles. Vehicles in a turning maneuver generate lateral acceleration; when critical lateral acceleration levels are reached, the inner wheels lift, and a rollover occurs. Rollover risk is actually higher on dry roads since the lower coefficients of friction of wet roads make the vehicle more likely to slide and less likely to roll. Of large truck–single vehicle crashes occurring in 2001, 18.4% of fatal crashes and 41.9% of injury crashes involved truck rollover as the first harmful event. When both single and multivehicle crashes are considered, these percentages are reduced to 4.5% and 7.1%, respectively (FMCSA, 2003a). Casualties occur in more than half of commercial vehicle rollovers (FMCSA, 2003b).

In addition to high centers of gravity, longer braking distances required by heavy vehicles and the fact that the articulation point on tractor–semitrailers prevents the driver from having a good proprioceptive (seat-of-the-pants) feel for their vehicle's level of lateral acceleration contribute to rollover risk at curved exit ramps. When combination-unit vehicles roll over, typically the semitrailer begins the roll and then flips the tractor. In multitrailer trucks, rearward amplification makes the last trailer particularly vulnerable to roll. When the last trailer rolls, it can either separate from the vehicle or flip the whole vehicle. Curved freeway exit ramps at cloverleaf interchanges are high-risk locations for heavy vehicles because of their need to reduce speed sharply and their inherent rollover risk factors. Ramps with decreasing radii present a particular hazard.

Harwood et al. (2003) conducted surveys of both trucking industry officials and state DOTs. The industry survey found that two thirds of motor carrier officials considered interchange ramps a high-priority safety concern at many locations. The state survey found three fourths of the DOT officials had safety problems with freeway exit ramps and more than half employed truck-specific warning signs at hazardous ramps. The use of advisory ramp speed limits for large trucks was reported by about one third of responding states. Such signage seems to be more effective if there are warning signs on the approach to the curve as well as in the curve.

Countermeasures against heavy vehicle rollovers on exit ramps include static, truck-specific warnings or advisory speeds, as mentioned above, and dynamic interactive signing (Harwood, 2003a). Figure 2 provides a schematic diagram of such interactive sign systems, which employ speed and weight sensors to identify heavy vehicles at-risk for rollover on the ramp. A truck-specific variable message sign or other advisory sign is activated when a rollover risk is detected. Systems vary in cost and sophistication. More elaborate systems also measure vehicle height to estimate center-of-gravity height and thus a more accurate prediction of rollover risk. Reducing the false alarm rate is important so that commercial drivers view the warnings as accurate and important (Harwood et al., 2003). Research issues relating to dynamic interactive rollover warnings include the optical system complexity for maximal cost–benefits and the most effective displays to reliably induce speed reduction by drivers.

The ITS IVI program has tested a vehicle-based rollover prevention system. The system incorporates information on vehicle load status and weight (affecting center-of-gravity height) in its warning algorithm. This vehicle-based system includes both control and advisory mechanisms of action. The roll stability control subsystem automatically slows the vehicle when imminent rollover risk is detected. The roll stability advisor is a driver training device rather than an imminent crash countermeasure. The advisor provides after-the-fact feedback to drivers regarding their rollover risk on curves. Using the system, drivers are able to learn to modify their driving behavior to reduce their rollover risk (FMCSA, 2003b and 2005).

Speed Limits for Heavy Vehicles

A reality of highway travel in North America and many other countries is widespread disregard for posted speed limits. Most drivers—of both heavy vehicles and light vehicles—exceed posted highway speed limits (Tardif, 2003, NHTSA, 1991). Although exceeding speed limits is

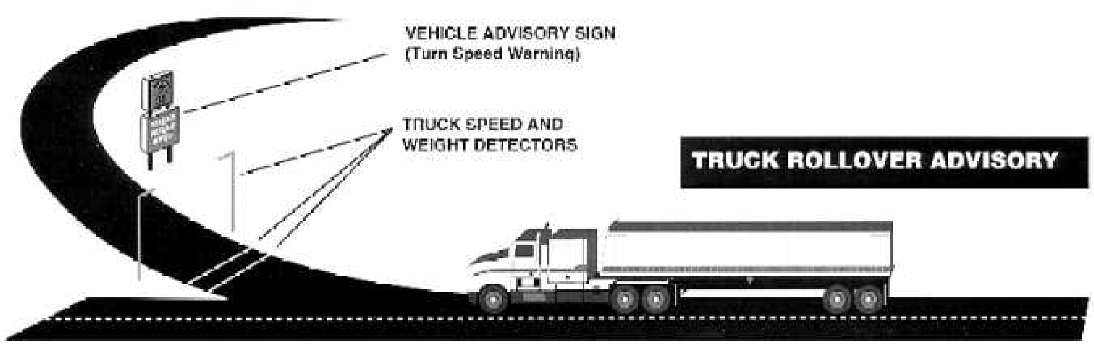

FIGURE 2 Schematic of an interactive truck rollover advisory system. (Source: Bureau of Highway Safety and Traffic Engineering, Pennsylvania DOT.)

common to both heavy and light vehicles, average highway speeds for heavy vehicles are generally 2 to 5 mph less than those of light vehicles. In addition, the percentage of heavy vehicles overspeeding (e.g., traveling at 80+ mph) is much less than the corresponding percentage of light vehicles. Hallmark and Isebrands (2004), evaluating speed differences for emissions modeling, collected average speeds and spot speeds for heavy trucks and passenger cars on arterial and freeway segments in Des Moines, Iowa, and Minneapolis–St. Paul, Minnesota. Average and spot speeds for heavy-duty trucks were lower than for passenger vehicles for all locations.

Because of their operational limitations, in particular their longer stopping distances and greater vulnerability to rollover on curves, lower highway speed limits for heavy vehicles may be appropriate. This is the rationale for differential light-vehicle–truck speed limits in which truck speed limits are 5 or 10 mph lower than light-vehicle speed limits (Harwood et al., 2003a; Garber et al., 2003). Harwood et al. (2003a) reported that about one third of the states employ differential speed limits for large trucks at some locations. An argument against differential speed limits and for uniform speed limits for all vehicles is the fact that uniform speeds reduce speed variance among all vehicles. This reduces interactions or “conflicts” among vehicles, particularly those that could result in rear-end crashes. Garber et al. (2003) have reviewed the literature and recent state experiences with differential and uniform speed limits for light vehicles and trucks on rural highways and have concluded that neither is consistently associated with reduced truck speeds or superior crash reduction. Part of the reason for no difference between one speed policy and the other is that speed limits are largely ignored by drivers and that prevailing highway speeds for all vehicles have risen over the past decade.

Harwood et al. (2003a) concluded that differentially reducing large truck speed limits by 5 mph is likely to reduce their prevailing speeds by 1 to 3 mph but that the safety effects of this are mixed or questionable. Light vehicle–into–truck rear-end crashes, for example, may increase. Overall, it appears that the relative safety merits of differential and uniform highway speed limits are debatable. What’s not questionable is the trucking industry view of differential speed limits; in a survey of 33 fleet safety managers and other industry officials (Harwood et al., 2003a), 26 (81%) felt that differential speed limits were undesirable or not needed. Only two industry respondents (6%) felt that they were highly desirable.

Intersections and Lane Merges

In recent research performed for FHWA, Council et al. (2004) used the Highway Safety Information System crash data and linked crash data with roadway inventory data to analyze critical crash type and roadway characteristics. The study found that there is a need to explore driver, vehicle, or roadway programs aimed at rural undivided roads and, in particular, at intersection segment angle and merging crashes and head-on crashes. Interstate and freeway treatments aimed at reducing car-truck crashes should concentrate on elements that affect lane-change/merging crashes and rear-end crashes.

Interestingly, the study also found truck drivers to be at fault in rear-end crashes (50.7% versus 41%), right-turn crashes involving vehicles on the same road (43.1% versus 35.5%), left-turn crashes involving an opposing vehicle on the same road (45.4% versus 38.6%), and sideswipe crashes (51.1% versus 35.1%).

Work Zones

The increased risk associated with construction zones compared with normal roadways is seen in naturalistic driving studies of commercial vehicle incident involvement. In a recently completed naturalistic study involving 48,000 h of recorded driving (Knipling et al., 2005), the conditions of occurrence of 915 safety-critical events were compared with those of 1,072 randomly selected driving epochs. Six percent of 915 safety-critical incidents occurred in construction zones, versus less than 1% of randomly selected baseline time epochs. The odds ratio of safety-critical events to baseline epochs in construction zones or related road sections compared with normal road sections was 8.5, a measure of the relative risk associated with these locations.

ATRI conducted a work zone study entitled Safety by Design: Optimizing Safety in Highway Work Zones (Murray, 2005). This study examined truck (26,000–80,000 lb) crashes in work zones in FARS and GES and compared studies of work zone crashes involving trucks in Ohio, New Mexico, Kentucky, Arizona, Georgia, and North Carolina. The authors discuss potential countermeasures including, driver feedback signing, rumble strips, highway advisory radio, and queue detection and warning. In addition, the researchers recommend additional data collection including large truck exposure to work zones and analyses to develop or improve work zone policies and employ strategies to reduce large-truck crash risk and severity in work zones.

WHERE ARE THE CRASHES HAPPENING?

The U.S. General Accountability Office (formerly General Accounting Office, GAO) reports that the roadway environment, that is, those factors external to the driver and the vehicle that increase the risk of a crash, is the second most prevalent factor cited as contributing to a crash (GAO, 2003). Preliminary analysis of the 985 crashes in FMCSA's LTCCS indicate that in two-vehicle crashes, the roadway was a related factor for 14% of the trucks and 16% of the other vehicles (Craft, 2005). GAO also reports that in 2001, rural roads handled only about 40% of all VMT, yet more than 60% of all fatalities occurred on rural roads. Truck crashes follow the same pattern. According to the *Trucks Involved in Fatal Accidents, Factbook 2000* (Matteson and Blower), 66% of the 5,567 fatalities in truck-involved crashes in 2000 occurred in rural areas. Table 2 shows the crash distribution by roadway class. (Tables 2 and 3 show the number of trucks involved in fatal accidents)

Although the Interstates carry the most truck traffic and have the highest percentage of commercial vehicles in the vehicle mix, they also have the highest design standards. Understandably most truck fatal accidents occur on the secondary system. Data for 2000 indicated that 75% of truck fatalities occur on non-Interstate roadways. Table 3 shows the fatal truck involvement by route signing (agency responsible for operation of roadway).

According to GAO (2004) rural roads make up about 77%, or 3 million miles, of the 3.9 million miles of the nations highways, and local rural roads (about 2.1 million miles) make up 68% of the rural roads. In addition, rural roads carry only about 40% of the traffic, with the rural local roads carrying about 5% of the traffic. Also, between 1990 and 2002, vehicle travel on rural roads increased by 27%, and commercial truck travel on rural roads increased by 32%. Many rural roads have narrow lanes, limited shoulders, limited sight distance, excessive curves, and steep side slopes. The Road Information Program (TRIP, 2005) reports that rural roads have

TABLE 2 Fatal Truck Involvement by Roadway Class (UMTRI, 2000)

Road Functional Class	Total	
	Number	Percent
Urban		
Interstate	498	9.4
Freeway/expressway	179	3.4
Other principal artery	484	9.2
Minor artery	236	4.5
Collector	59	1.1
Local street	155	2.9
Unknown urban	24	0.5
Total urban	1,635	31.0
Rural		
Interstate	805	15.3
Other principal artery	1,125	1.3
Minor artery	603	11.4
Major collector	520	9.9
Minor collector	116	2.2
Local road	192	3.6
Unknown rural	118	2.2
Total rural	3,479	66.0
Unknown	161	3.1
Total urban and rural	5,275	100.0

TABLE 3 Fatal Truck Involvement by Route Signing (UMTRI, 2000)

Route Signing	Number	Percent
Interstate	1,340	25.4
U.S. highway	1,386	26.3
State highway	1,517	28.8
County road	445	8.4
Township	71	1.3
Municipality	334	6.3
Frontage road	16	0.3
Other	145	2.7
Unknown	21	0.4
Total	5,275	100.0

often been constructed over a period of years and as a result often have inconsistent design features for such things as lane widths, curves, shoulders, and clearance zones.

FUTURE RESEARCH NEEDS

FMSCA Research and Technology 5-Year Strategic Plan, recognizes the significance of the compatibility of trucks and the roadway environment in crash reduction (McKelvey, 2005). “The impact of physical road configuration (work zones, ramps, and intersections)" is a key area in the goal to improve truck and motorcoach performance through vehicle based safety technologies as part of an objective to improve safety of CMVs.

The relationship of congestion to safety is complex and not well defined and is an area of future research particularly relative to trucks and rear end collisions. Another area for future research is the relationship of various design features when taken together. In the White Plains cargo tank accident discussed earlier, NTSB found that although the design features encountered by the truck were within the minimum standards when encountered together, the truck lost stability. Safety knowledge largely addresses one design element at a time. The interactions between geometric elements are poorly understood; examples include superelevated horizontal curves on downgrades, ramp curvature, and superelevation.

As discussed above, the majority of truck-related fatalities are occurring on rural secondary roads. These roads are also experiencing the greatest proportion of truck VMT growth. Not much is known about the extent of these secondary roads that are below minimum standards or an inventory of the various combinations of design standards that may be troublesome to trucks. Policy makers need this information to make intelligent decisions regarding the funding of safety improvements.

NOTE

1. Instrumented vehicle studies detect the occurrence of traffic conflicts and other safety-critical events by the use of dynamic triggers such as hard braking and swerve. Comparing the roadway locations of incidents with those of randomly selected control time periods provides a measure of the increased or decreased risk associated with various environmental locations and conditions.

REFERENCES

Council, F., et al. *An Examination of Fault, Unsafe Driving Acts, and Total Harm in Car-Truck Collisions*. FHWA-HRT-04-085. Highway Safety Information System, FHWA, U.S. Department of Transportation, 2004.

Craft, R. TRB Annual Meeting, Session 119: Federal Motor Carrier Safety Administration Research and Technology: Today and Tomorrow. Presented at 84th Annual Meeting of the Transportation Research Board, Washington, D.C., 2005.

FMCSA. *Large Truck Crash Facts 2001*. FMCSA-RI-02-011. FMCSA, U.S. Department of Transportation, 2003a.

FMCSA. *Large Truck Crash Facts 2002*. FMCSA-RI-04-021. FMCSA, U.S. Department of Transportation, 2004.

FMCSA. Intelligent Vehicle Initiative Onboard Safety Technology Workshop. FMCSA, U.S. Department of Transportation, 2003b.

FMCSA. *Concept of Operations and Voluntary Operational Requirements for Vehicular Stability Systems (VSS) On-Board Commercial Motor Vehicles*. FMCSA-MCRR-05-006. FMCSA, U.S. Department of Transportation, 2005.

Garber, N. J., J. S. Miller, B. Yuan, and X. Sun. Safety Effects of Differential Speed Limits on Rural Interstate Highways. *Transportation Research Record: Journal of the Transportation Research Board, No. 1830*, Transportation Research Board of the National Academies, Washington, D.C., 2003, pp. 56–62.

GAO. *Highway Safety, Federal, and State Efforts to Address Rural Road Safety Challenges*. GAO-04-663. U.S. General Accounting Office, May 2004.

GAO. *Highway Safety-Research Continues on a Variety of Factors That Contribute to Motor Vehicle Crashes*. GOA-03-436. U.S. General Accounting Office, March 2003.

Hallmark, S. L., and H. Isebrands. *Evaluating Speed Differences Between Passenger Vehicles and Heavy Trucks for Transportation-Related Emissions Modeling*. DTFH61-03-P-00336. Iowa State University, July 2004.

Harwood, D. W., J. M. Mason, W. D. Glauz, B. T. Kulakowski, and K. Fitzpatrick. *Truck Characteristics for Use in Highway Design and Operation*. Vol. 1. FHWA_RD_89-226. FHWA, U.S. Department of Transportation, August 1990.

Harwood, D. W., I. B. Potts, D. J. Torbic, and W. D. Glauz. *CTBSSP Synthesis of Safety Practice 3: Highway/Heavy Vehicle Interaction*. Transportation Research Board of the National Academies, Washington, D.C., 2003.

Harwood, D.W., D. J. Torbic, K. R. Richard, W. D. Glauz, and L. Elefteriadou. *NCHRP Report 505: Review of Truck Characteristics as Factors in Roadway Design.* Transportation Research Board of the National Academies, Washington, D.C., 2003.

Knipling, R. R., R. J. Hanowski, J. S. Hickman, R. L. Olson, T. A. Dingus, and R. J. Carroll. Exposure-Risk Analysis of Large Truck Naturalistic Driving Data. *Proc., 2005 Truck and Bus Safety and Security Symposium*, Alexandria, Va., November 14–16, 2005.

Matteson, A., and D. Blower. *Trucks Involved in Fatal Accidents, Factbook 2000*. UMTRI 2003-20. Center for National Truck Statistics, University of Michigan Transportation Research Institute, Ann Arbor, July 2003.

McKelvey, D. Session 119: FMCSA Research and Technology: Today and Tomorrow. Presented at 84th Annual Meeting of the Transportation Research Board, Washington, D.C., 2005.

Murray, D. C., K. Wahl, and R. M. Brewster. *Safety by Design: Optimizing Safety in Highway Work Zones.* American Transportation Research Institute, Alexandria, Va., September 2005.

NHTSA. *Commercial Motor Vehicle Speed Control Devices*. DOT HS 807 725. Office of Crash Avoidance Research, NHTSA, U.S. Department of Transportation, 1991.

NTSB. *Propane Truck Collision with Bridge Column and Fire, White Plains, New York, July 27, 1994.* NTSB/HAR-95/02. NTSB, U.S. Department of Transportation, 1995.

Tardif, L.-P. *Speeding: Climate Change and Road Safety Implications for Heavy Freight Vehicles.* Final Report prepared for Natural Resources Canada Office of Energy Efficiency and Transport Canada Road Safety Directorate, March 2003.

TRIP. *Growing Traffic in Rural America: Safety Mobility and Economic Challenges in America's, Heartland*. The Road Information Program, March 2005. Available at www.tripnet.org.

APPENDIX A

List of Authors

Albert Alvarez
Federal Motor Carrier Safety Administration
Albert.alvarez@dot.gov

Michael H. Belzer
Wayne State University
michael.h.belzer@wayne.edu

Gene Bergoffen
MaineWay Services
bergoffen@fairpoint.net

Daniel Blower
Center for National Truck Statistics
University of Michigan Transportation Research Institute
dfblower@umich.edu

Rebecca M. Brewster
American Transportation Research Institute
rbrewster@trucking.org

Kenneth L. Campbell*
Transportation Research Board
kcampbell@nas.edu
*Written while author was with the Oak Ridge National Laboratory

Stephen F. Campbell, Sr.
Commercial Motor Vehicle Safety Alliance
scampbell@cvsa.org

Robert M. Clarke
Truck Manufacturers Association
robertmclarke@truckmfgs.org

Roger D. Clarke
Alberta Transportation
roger.clarke@gov.ab.ca

Deborah M. Freund
Federal Motor Carrier Safety Administration
deborah.freund@dot.gov

Richard J. Hanowski
Virginia Tech Transportation Institute
rhanowski@vtti.vti.edu

Douglas W. Harwood
Midwest Research Institute
dharwood@mriresearch.org

E. Lee Husting
Centers for Disease Control
eih8@cdc.gov

Stephen A. Keppler
Commercial Vehicle Safety Alliance
stevek@cvsa.org

Helmut E. Knee
Oak Ridge National Laboratory
kneehe@ornl.org

Ronald R. Knipling*
Independent consultant
rknipling@vtti.vt.edu
*Written while author was with the Virginia Tech Transportation Institute

Robert Kreeb
Booz, Allen & Hamilton, Inc.
Kreeb_bob@bah.com

Gerald P. Krueger
Wexford Group International
gkrueger@thewexfordgroup.com

Brenda M. Lantz
North Dakota State University/ Great PlainsTransportation Institute
brenda.lantz@ndsu.edu

Anne T. McCartt
Insurance Institute for Highway Safety
AMcCartt@iihs.org

Michele Ann McMurtry*
McMorgan Group
michelemcmurtry@mac.com
*Written while author was with the National Transportation Safety Board

David F. Melton
Transportation Technical Consulting Services
Liberty Mutual Research Institute for Safety
david.melton@libertymutual.com

Michael Perel
National Highway Traffic Safety Administration
Mike.Perel@dot.gov

Duane A. Perrin*
Truxpertise, LLC
duane@e-perrin.com
*Written while author was with the National Highway Traffic Safety Administration

Paul Rau
National Highway Traffic Safety Administration
prau@nhtsa.dot.gov

William C. Rogers
Federal Aviation Administration
Bill.Rogers@faa.gov

Robert A. Scopatz
Data Nexus, Inc.
bscopatz@data-nexus.com

John H. Siebert
Owners and Operators Independent Drivers Association Foundation, Inc.
john_siebert@ooida.com

Margaret Sweeney
National Transportation Safety Board
Margaret.Sweeney@ntsb.gov

Alrik Svenson
National Highway Traffic Safety Administration
Alrik.svenson@nhtsa.dot.gov

Joel L. Ticatch
Telvent Farradyne, Inc.
Joel.Ticatch@telvent.abengoa.com

APPENDIX B

List of Acronyms

AASHO	American Association of State Highway Officials
ABS	antilock brake system
AMA	American Medical Association
ATA	American Trucking Associations
ATRI	American Transportation Research Institute
BAC	blood alcohol content
BBS	behavior-based safety
BIFA	Buses Involved in Fatal Accidents
BLS	Bureau of Labor Statistics
BMI	body mass index
BTW	behind-the-wheel
CB	citizen band
CDC	Centers for Disease Control
CDL	commercial drivers license
CDLIS	CDL Information System
CDS	Crashworthiness Data System
CFOI	Census of Fatal Occupational Injuries
CMV	commercial motor vehicle
CMVSA	Commercial Motor Vehicle Safety Act of 1986
COMS	California Occupational Mortality Study
CR	compliance review
CRP	cooperative research project
CSA	Canadian Standards Association
CSMS	carrier safety management system
CVD	cardiovascular disease
CVISN	Commercial Vehicle Information Systems and Networks
CVO	commercial vehicle operator
CVSA	Commercial Vehicle Safety Alliance
CWS	collision warning system
DFAS	Driver Fatigue and Alertness Study
DMS	Docket Management System
DOT	department of transportation
DSRC	dedicated short-range communications
EA	environmental assessment
ECBS	electronically controlled braking system
ECU	electronic control unit
EDR	event data recorder
EEG	electroencephalograph

EIS	environmental impact statement
ESP	enhanced stability programs
ETT	exercise tolerance stress test
FARS	Fatality Analysis Reporting System
FCC	Federal Communications Commission
FDA	U.S. Food and Drug Administration
FLSA	Fair Labor Standards Act
FMCSA	Federal Motor Carrier Safety Administration
FMCSR	federal motor carrier safety regulation
FMP	fatigue management program
FMVSS	federal motor vehicle safety standard
FOT	field operational test
F-SHRP	Future Strategic Highway Research Program
GAO	U.S. General Accountability Office (formerly General Accounting Office
GES	General Estimates System
GIG	Gettin' in Gear Program
GPS	Global Positioning System
GVWR	gross vehicle weight ratings
hazmat	hazardous materials
HDL	high-density lipoprotein
HD-ODB	heavy-duty onboard diagnostic
HMR	hazardous materials regulations
HMTA	Hazardous Materials Transportation Act of 1974
HOS	hours of service
ICC	Interstate Commerce Commission
IHD	ischemic heart disease
ISS	Inspection Selection System
ISTEA	Intermodal Surface Transportation Efficiency Act of 1991
ITS	intelligent transportation system
IVI	Intelligent Vehicle Initiative
LTCCS	Large Truck Crash Causation Study
MCA	Motor Carrier Act
MCMIS/Crash	Motor Carrier Management Information System Crash Profile
MCSAP	Motor Carrier Safety Assistance Program
MCSIA	Motor Carrier Safety Improvement Act
METS	resting metabolic rate
NAFTA	North American Free Trade Agreement
NASS	National Automotive Sampling System
NDR	National Driver Register
NEPA	National Environmental Policy Act of 1969
NIOSH	National Institute for Occupational Safety and Health
NN	national network (the Interstate system and other Federal-Aid Primary Highways)
NPTC	National Private Truck Council
NTSB	National Transportation Safety Board

NTTAA	National Technology Transfer and Advancement Act of 1995
OIRA	Office of Information and Regulatory Affairs
OMB	Office of Management and Budget
OMC	Office of Motor Carriers
OOIDA	Owner–Operator Independent Drivers Association
OSH Act	Occupational Safety and Health Act
OSHA	Occupational Safety and Health Administration
PAR	police accident report
PERCLOS	percent of eye closure
PHMSA	Pipeline and Hazardous Materials Safety Administration
PIC	Partners in Compliance
PRISM	Performance and Registration Information Systems Management
PSU	primary sampling units
PVT	psychomotor vigilance task
R&D	research and development
REM	rapid eye movement
RLS	restless leg syndrome
SAFER	Safety and Fitness Electronic Records
SAFETEA-LU	Safe, Accountable, Flexible, Efficient Transportation Equity Act: A Legacy for Users
STAA	Surface Transportation Assistance Act
TEA-21	Transportation Equity Act for the 21st Century
TIFA	Trucks Involved in Fatal Accidents
TRB	Transportation Research Board
TRIP	The Road Information Program
TRL	Transport Research Laboratory, U.K.
UMTRI	University of Michigan Transportation Research Institute
VDR	vehicle data recorder
VIN	vehicle identification number
VIUS	Vehicle Inventory and Use Survey
VMT	vehicle miles traveled

THE NATIONAL ACADEMIES

Advisers to the Nation on Science, Engineering, and Medicine

The **National Academy of Sciences** is a private, nonprofit, self-perpetuating society of distinguished scholars engaged in scientific and engineering research, dedicated to the furtherance of science and technology and to their use for the general welfare. On the authority of the charter granted to it by the Congress in 1863, the Academy has a mandate that requires it to advise the federal government on scientific and technical matters. Dr. Ralph J. Cicerone is president of the National Academy of Sciences.

The **National Academy of Engineering** was established in 1964, under the charter of the National Academy of Sciences, as a parallel organization of outstanding engineers. It is autonomous in its administration and in the selection of its members, sharing with the National Academy of Sciences the responsibility for advising the federal government. The National Academy of Engineering also sponsors engineering programs aimed at meeting national needs, encourages education and research, and recognizes the superior achievements of engineers. Dr. William A. Wulf is president of the National Academy of Engineering.

The **Institute of Medicine** was established in 1970 by the National Academy of Sciences to secure the services of eminent members of appropriate professions in the examination of policy matters pertaining to the health of the public. The Institute acts under the responsibility given to the National Academy of Sciences by its congressional charter to be an adviser to the federal government and, on its own initiative, to identify issues of medical care, research, and education. Dr. Harvey V. Fineberg is president of the Institute of Medicine.

The **National Research Council** was organized by the National Academy of Sciences in 1916 to associate the broad community of science and technology with the Academy's purposes of furthering knowledge and advising the federal government. Functioning in accordance with general policies determined by the Academy, the Council has become the principal operating agency of both the National Academy of Sciences and the National Academy of Engineering in providing services to the government, the public, and the scientific and engineering communities. The Council is administered jointly by both the Academies and the Institute of Medicine. Dr. Ralph J. Cicerone and Dr. William A. Wulf are chair and vice chair, respectively, of the National Research Council.

The **Transportation Research Board** is a division of the National Research Council, which serves the National Academy of Sciences and the National Academy of Engineering. The Board's mission is to promote innovation and progress in transportation through research. In an objective and interdisciplinary setting, the Board facilitates the sharing of information on transportation practice and policy by researchers and practitioners; stimulates research and offers research management services that promote technical excellence; provides expert advice on transportation policy and programs; and disseminates research results broadly and encourages their implementation. The Board's varied activities annually engage more than 5,000 engineers, scientists, and other transportation researchers and practitioners from the public and private sectors and academia, all of whom contribute their expertise in the public interest. The program is supported by state transportation departments, federal agencies including the component administrations of the U.S. Department of Transportation, and other organizations and individuals interested in the development of transportation.
www.TRB.org

www.national-academies.org

TRB
TRANSPORTATION RESEARCH BOARD
500 Fifth Street, NW
Washington, DC 20001