CONFERENCE PROCEEDINGS 38

Future Truck and Bus Safety Research Opportunities

TRANSPORTATION RESEARCH BOARD
OF THE NATIONAL ACADEMIES

CONFERENCE PROCEEDINGS 38

Future Truck and Bus Safety Research Opportunities

Sponsored by
Federal Motor Carrier Safety Administration
Transportation Research Board

March 23–24, 2005
Arlington, Virginia

TRANSPORTATION RESEARCH BOARD
OF THE NATIONAL ACADEMIES

Washington, D.C.
2006
www.TRB.org

Transportation Research Board Conference Proceedings 38
ISSN 1073-1652
ISBN 0-309-09422-4

Subscriber Category
IVB safety and human performance

Transportation Research Board publications are available by ordering individual publications directly from the TRB Business Office, through the Internet at www.TRB.org or national-academies.org/trb, or by annual subscription through organizational or individual affiliation with TRB. Affiliates and library subscribers are eligible for substantial discounts. For further information, contact the Transportation Research Board Business Office, 500 Fifth Street, NW, Washington, DC 20001 (telephone 202-334-3213; fax 202-334-2519; or e-mail TRBsales@nas.edu).

Printed in the United States of America.

NOTICE: The project that is the subject of this report was approved by the Governing Board of the National Research Council, whose members are drawn from the councils of the National Academy of Sciences, the National Academy of Engineering, and the Institute of Medicine. The members of the committee responsible for the report were chosen for their special competencies and with regard for appropriate balance.

This report has been reviewed by a group other than the authors according to the procedures approved by a Report Review Committee consisting of members of the National Academy of Sciences, the National Academy of Engineering, and the Institute of Medicine.

The conference was sponsored by the Transportation Research Board and the Federal Motor Carrier Safety Administration of the U.S. Department of Transportation.

Committee on Future Truck and Bus Safety Research Opportunities: A Conference
H. Douglas Robertson, Highway Safety Research Center, University of North Carolina at Chapel Hill, *Chair*
John R. Berry, Risk Management, FedEx Freight
Stephen F. Campbell, Sr., Commercial Vehicle Safety Alliance
Robert M. Clarke, Truck Manufacturers Association
Alan M. Clayton, University of Manitoba
Michael E. Conyngham, International Brotherhood of Teamsters
Alessandro Guariento, Greyhound Lines, Inc.
E. Lee Husting, National Institute for Occupational Safety and Health
Ronald R. Knipling, Virginia Tech Transportation Institute
Kevin Lewis, American Association of Motor Vehicle Administrators
Anne T. McCartt, Insurance Institute for Highway Safety
John H. Siebert, Owner-Operator Independent Drivers Association Foundation

Transportation Research Board Staff
Richard F. Pain, Transportation Safety Coordinator
Joanice L. Cole, Senior Program Assistant
Susan B. Herbel, Consultant

TRB Publications Office
Naomi Kassabian, Editor
Ann E. Petty, Managing Editor
Norman Solomon and Patricia Spellman, Production Editors
Jennifer J. Weeks, Editorial Services Specialist
Mary McLaughlin, Proofreader

Cover design by Tony Olivis, Studio 2
Typesetting by Carol Levie, Grammarians

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

Contents

Preface

On March 23 and 24, 2005, a group of industry, government, university, and consultant experts gathered in Arlington, Virginia, to participate in a conference on future truck and bus research opportunities. The purpose was to ponder the future of the commercial vehicle industry and to identify research requirements in preparation for the proposed future. The conference was jointly sponsored by the Transportation Research Board and the Federal Motor Carrier Safety Administration.

The conference was planned and conducted under the auspices of a specially appointed committee convened by the National Research Council. The purpose of the project was to examine future scenarios and consider the following questions: What will the future be like in terms of truck and bus travel? What will be the impact of the anticipated conditions on safety? What research should be accomplished to prepare for the future? Some related issues, such as potential barriers to implementation of research findings, were briefly raised during the conference and their importance noted. Because such issues go beyond the scope of this project, however, they were not a focus of conference or committee discussions, and they are not addressed in this report.

Conference Themes

The conference was organized around a number of themes related to truck and bus safety. A diverse mixture of papers and other presentations, panel discussions, and provocateurs provided background information and stimulated participant thinking and dialogue. It was proposed that attendees think outside the box in the best sense of the phrase, not only to address an unknown future but also to think seriously about the consequences of that future and suggest research topics that would help prepare for uncertain circumstances. The following themes were addressed (see Appendix A for the formal agenda):

- 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.

Sessions generally began with a thought-provoking commentary and most included formal presentations followed by a panel discussion. Panelists were given the responsibility and opportunity to offer their own unique insights as well as to react to the comments of moderators, provocateurs, and other speakers. Each session ended with audience discussion in which everyone was considered an expert and encouraged to participate.

Report Organization

These proceedings summarize the issues, comments, future scenarios, and other information addressed during the conference, organized according to the themes.

The authored research papers presented at the conference are also included. Each chapter includes future scenarios as described by the speakers. In some cases, the speakers believed it necessary to begin with a reality check and described current conditions as a prologue to their visions of the future. The chapters also contain a synopsis of the discussions and presentations and the research needs cited, along with the appropriate research papers. The conference committee met following the event to synthesize the information presented and discussions held and to deliberate on its findings and recommendations for future research. The committee's findings and recommendations are presented at the start of these proceedings.

Acknowledgments

This conference would not have been possible without the financial and institutional support of the Federal Motor Carrier Safety Administration. Special thanks are extended to Albert Alvarez, Program Manager, and Gianluigi Caldiera, FMCSA consultant, for their support and assistance. Richard F. Pain, TRB Transportation Safety Coordinator, worked with the committee to plan the conference under the guidance of the committee and the supervision of Mark Norman, TRB Director of Technical Activities. Suzanne Schneider, Associate Executive Director of TRB, managed the report review process. Thanks are extended to Susan B. Herbel, consultant, for her work in assembling and preparing these proceedings under the guidance of the committee.

The papers, presentations, discussions, and summaries of the views expressed by conference speakers and participants are intended to provide a record of the conference. The views expressed do not necessarily reflect those of the conference committee, TRB, NRC, or the project's sponsors.

This report was reviewed in draft form by individuals chosen for their diverse perspectives and technical expertise, in accordance with procedures approved by NRC's Report Review Committee. The purpose of this independent review is to provide candid and critical comments that assist the institution in making the published report as sound as possible and to ensure that the report meets institutional standards for objectivity, evidence, and responsiveness to the project charge. The review comments and draft manuscript remain confidential to protect the integrity of the deliberative process.

The committee thanks the following individuals for their review of this report: Daniel Blower, University of Michigan Transportation Research Institute; William Mahorney, Federal Highway Administration; Stephanie Pratt, National Institute for Occupational Safety and Health; and David K. Willis, Texas Transportation Institute, Texas A&M University. Although these reviewers provided many constructive comments and suggestions, they were not asked to endorse the report's findings and conclusions, nor did they see the final draft before its release.

The review of this report was overseen by C. Michael Walton, University of Texas at Austin. Appointed by NRC, he was responsible for making certain that an independent examination of this report was carried out in accordance with institutional procedures and that all review comments were carefully considered. Responsibility for the final content of this report rests entirely with the authoring committee and the institution.

Committee Findings and Recommendations

In 20 years, what will this nation's roads and highways look like, and, more important, how will trucks and buses safely and efficiently navigate those highways? A group of industry, government, and university experts met at the Conference on Future Truck and Bus Safety Research Opportunities in Arlington, Virginia, on March 23 and 24, 2005, to consider these questions and to explore the types of research needed to meet the challenges of the future. The conference was jointly sponsored by the Transportation Research Board and the Federal Motor Carrier Safety Administration.

The conference was planned and conducted under the auspices of a specially appointed committee convened by the National Research Council. After the conference on future truck and bus safety research opportunities, the committee met for 2 days to review the information presented and discussed at the conference and to develop a set of research recommendations. The committee's recommendations are set forth below, organized according to the structure of topic themes used at the conference.

During the next 5 years, the amount of data collected by carriers and government agencies will grow exponentially. Both entities will struggle with the resource requirements for managing and analyzing the data while at the same time carriers and drivers will protect themselves from the potential liability related to data access. These conditions, though not directly addressed in any one session, formed the overriding theme during the conference and affect many of the issues discussed.

1. Problem Assessment

As in the past, resources are devoted at both the federal and state levels to data collection. The data are used primarily for enforcement purposes, such as targeting those carriers with a history of regulatory noncompliance and high crash rates. In some cases, the data are also used to influence the deployment of enforcement resources. To the extent that research is conducted, for the most part it has been focused on examining a series of independent variables to identify crash risk factors or to define and identify problematic drivers and carriers.

Research is made more difficult by several conditions. As discussed in several presentations during the conference, there are large gaps in exposure data, such as vehicle miles of travel, number of carriers, number and characteristics of drivers, type of roadway, and time of day. State reporting of crash and inspection data is weak and often out of date; reliable and representative data on nonfatal large-truck crashes are almost nonexistent; and a good system for linking carriers to crashes is lacking.

To conduct research successfully with promise for improving truck and bus safety requires improvements in the collection and management of enforcement data, recognition of the value of conducting studies with specific research questions and samples of data to address those questions, and effectively accessing and utilizing data from onboard recorders and other technologies.

To move the research agenda forward, there is a need for a continuing series of studies based on statistical samples that consider all the characteristics of crashes and methods for measuring, understanding, and forecasting safety-related exposure parameters. It is not a matter of eliminating current methods and processes; rather the key is to identify new and more effective measures of safety. Better data and exposure measures will lead to more effective research in terms of identifying the real risk factors and addressing them.

Assessing the scope and nature of the large-truck and bus crash problem is essential for developing countermeasures that are directed most effectively at reducing the problem. Given the complexity of the large-truck and bus safety issues and limited research funds, the following recommendations seek to address the most critical research needs in a cost-effective manner.

Recommendation 1(a)

A series of studies should be conducted to develop exposure-based rates and quantify the risk factors associated with large-truck crashes. This effort should involve

- Quantifying crash rates on the basis of important exposure variables such as vehicle miles traveled by type of roadway and type of carrier, interstate versus intrastate carriers, time of day, and number of registered vehicles and drivers with commercial driver's licenses (CDLs);
- Improving the capability to link crashes to carrier and driver information;
- Establishing an ongoing data collection effort, using statistical sampling methods as needed, to gather reliable data on nonfatal large-truck and bus crashes, large vehicle fleets, and vehicle miles traveled by roadway type, time of day, and other key exposure and risk factors; and
- Quantifying specific driver, vehicle, and environmental crash risk factors that incorporate reliable exposure data or use case-control methods.

Recommendation 1(b)

Increased intermodal freight and passenger transport should provide research opportunities for studying the efficient use of alternative combinations of modes (highway, marine, air, and rail). Given projected increases in freight flows and volumes, particularly international traffic (see Future Scenario, Pisarski, Chapter 1), the interface between modes should be studied for new ways to improve coordination and operation of intermodal transfer. As mentioned throughout the conference but especially in the opening session (see Chapter 1), capacity constraints in many modes will mean that mechanisms for effectively using modes both individually and in combination will be required. Similarly, the coordination and interconnectivity of passenger movement will need continued research to identify best practices and new methods.

2. Human Performance and Behavior

There is a widespread perception that a small percentage of drivers are responsible for an inordinate amount of the fleet crash risk. This hypothesis has not been proved, but some empirical data support the notion. This idea is particularly appealing, especially if the specific risk factors could be identified and linked to driver, vehicle, environmental, and management characteristics and practices. However, the same hypothesis was studied with respect to passenger vehicle drivers and found not to be valid, at least not to the extent expected. Experience in the passenger vehicle safety area also has found that general deterrence efforts aimed at preventing risk-taking behavior among the general population of drivers can be highly effective for high-risk drivers as well as for other drivers.

Past and current research tends to focus on specific risk factors. The conference presentations and discussions described the literature and presented new research on driver demographics, such as age and gender; driver behavioral histories, prior crashes, and violation rates; driver physical and medical characteristics, including obesity and a variety of sleep disorders; driver performance capabilities, attentional demands, and useful field of view; driver personalities and off-duty behavior; carrier operational and management practices, training practices, and safety practices; driving actions and behaviors; vehicle factors; and situational and environmental factors, such as type of roadway and weather. In all cases, the individual factors have been shown to correlate to varying degrees with an increase in crash risk. Despite a plethora of studies, a comprehensive model to show the interactive or relative effects among the risk factors has not been developed. In other words, kernels of knowledge exist, but the underlying causes of the risk factors remain elusive. For example, the nature of the interaction between driver characteristics and the nature of the job is unknown.

Onboard recorders, instrumented vehicles, and other technologies have been touted as the means to gather data supporting such research. With data gathered from the black boxes, researchers would be better able to document driver behavior on the road and could study the effects of particular risk factors as well as the interactive effects of multiple risk factors. However, this silver bullet leads to the question of how drivers will react to the technology. Although they are employees of a regulated industry, truck drivers are entitled to the rights and privileges of all citizens, including the right to privacy. Drivers must be convinced that the technology will improve their safety and the safety of all drivers and that their privacy rights are respected or they will sabotage the technology regardless of whether it is used for management or research purposes.

These recommendations seek to capitalize on technologies available to collect accurate information on driver behaviors on the road and thereby identify problematic driver behaviors and characteristics so that interventions can occur before, rather than after, a crash has occurred. Whether countermeasures are identified and focused on high-risk drivers or on conditions leading to risky behaviors, such as fatigued driving, developing a better understanding of the nature, scope, and origin of driver risk factors can be expected to reduce crashes involving large trucks and buses substantially.

Recommendation 2(a)

Sampling, data filtering, data classification and coding, quality control, and data documentation practices should be developed to refine methodologies for the reduction and analysis of naturalistic driving data. These practices should encompass both incident data (e.g., crashes, near crashes, and other traffic conflicts) and baseline exposure data. Goals of this endeavor include validation of naturalistic driving data (e.g., triggering events), establishment of rigorous data coding and analysis protocols, and ensuring of compatibility of naturalistic driving data and crash data for synergistic analyses. The research should use strong scientific research designs and involve

- Quantifying risk factors by using case-crossover methods or exposure data;
- Refining and validating driver, vehicle, and environmental measures;
- Validating the relationship between measures of noncrashes, such as near misses and lane departures, and crash likelihood; and
- Using driver samples of adequate size that are representative of the truck driver and carrier population and that minimize volunteer and other biases.

Recommendation 2(b)

An assessment should be made of how and to what extent drivers use various types of crash avoidance in-vehicle technologies and the effects of multifunctional in-vehicle technologies on levels of driver distraction, improvements or decrements in driving performance, and cognitive overload.

Recommendation 2(c)

Prevention programs for minimizing fatigue in the context of commercial vehicle drivers' lifestyle choices, shifting workforce demographics, and the changing nature of the occupation should be developed and rigorously evaluated.

Recommendation 2(d)

Fitness-for-duty standards should be developed and rigorously validated and their effects on driver fatigue and crash involvement should be examined. A comprehensive onboard system for monitoring both drivers and vehicles should also be designed and validated.

Recommendation 2(e)

A system for enforcing driver work rules based on mandatory electronic onboard recorders should be developed, implemented, and evaluated, and research using these data to relate rule violations to driver and carrier characteristics should be conducted.

Recommendation 2(f)

Individual differences related to fatigue, inattention, traffic law violations, and other commercial driver risk factors should be studied systematically and quantitatively. The interaction between degree of risk and personal characteristics related to medical condition, performance, personality, demographics, and behavioral history should also be quantified.

3. Enforcement, Compliance with Regulations, and Security Management

Combination vehicles with mechanical defects are about 1.7 times more likely to crash than those without defects. Presentations and discussions during the conference demonstrated the effectiveness of enforcing federal commercial vehicle safety regulations. Although it is impossible to quantify the effects precisely, it can be assumed that compliance with regulations reduces crash risk, and a goal should be established to eliminate crashes attributable to mechanical defects. Even though the inspection selection process is focused toward trucks and carriers most likely to be in violation of federal regulations, the fact remains that one in three combination vehicles inspected is placed out of service during a Level 1 inspection, which covers safety-related items such as steering, brakes, cracked frame members, and lights.

A number of vehicle safety technologies (e.g., electronic stability control and automatic brake adjusters) have the potential to substantially reduce certain types of truck crashes. However, many of these technologies are expensive, and the benefits from a reduction in crashes are shared by other drivers and society as well as by carriers. When research indicates large safety benefits, regulation to require these technologies or provide incentives for their use should be considered. With wider use, it can be assumed that per unit costs will decline.

Regulations focused on drivers also are important and provide the means to ensure that drivers are well qualified and trained and have work schedules that enable them to drive alert and well rested. These regulations also provide a means to identify problematic drivers with poor safety records and provide appropriate remedial action, including removal of a CDL if indicated. Driver regulations that are sound and effectively enforced are important in reducing driver-related crashes.

Studies of motor carrier risk conducted by DOT's Volpe Center (available at http://ai.volpe.dot.gov/maspa.asp) show that at-risk carriers identified through SafeStat have future crash rates that are more than twice the industry average. Moreover, an effectiveness study of roadside inspections conducted by the Volpe Center in 2004 showed that more than 12,000 crashes, 9,000 injuries, and 500 fatalities are prevented annually by commercial vehicle roadside inspections.

Both the commercial motor vehicle miles traveled and the number of commercial motor vehicles will increase by an estimated 60% to 70% by 2005 (see Shaffer, Freund, Loy, and Minor, p. 24). Current enforcement methods reach only a small percentage of carriers, vehicles, and drivers. The enforcement process is extremely time- and personnel-intensive. Hiring and training more enforcement officers is not the solution. Research is needed in a number of areas to improve enforcement and compliance. Methods are needed for inspecting a larger number of carriers and vehicles without interrupting the movement of people and goods and for reducing the risk to officers at the roadside. Technologies provide an obvious way to improve the effectiveness and efficiency of enforcement, but, as noted earlier, these technologies must be implemented in a way that protects driver and carrier privacy and addresses liability issues. The potential benefits of research in this area are related not only to safety improvements but also to personnel and financial savings.

Recommendation 3(a)

A feasibility study of carrier and driver performance and incentive-based systems for ensuring effective compliance with vehicle regulatory requirements, which would reduce reliance on regulations and monitoring, should be developed, conducted, and evaluated.

Recommendation 3(b)

Alternative methods should be evaluated for ensuring that vehicle safety requirements are met, including licensed or enfranchised third-party or self-certifying annual vehicle inspections and advanced technologies.

Recommendation 3(c)

Research should be conducted to identify and validate the elements of effective carrier safety management programs that can be implemented by intrastate and regional small and medium-sized carriers.

4. Driver Health and Wellness

According to discussions during the conference, the health and wellness of truck and bus drivers has not been thoroughly documented, in contrast to the well-known public health problem of fatalities involving commercial vehicles. Furthermore, the relationship between driver health and wellness and crash risk has not been established through research and currently is not understood. Health costs are difficult to quantify because the consequences are long term and cumulative. There is often a long delay between exposure and illness. Drivers are exposed to a variety of conditions that are conducive to poor health, such as long hours and irregular sleep cycles.

The medical requirements for obtaining a CDL are intended to ensure a reasonable level of baseline health and fitness to drive. However, preliminary evidence suggests that commercial drivers may be at increased risk of early mortality and various chronic illnesses related to the lifestyle. Lack of exercise and unbalanced diets may lead to obesity, cardiovascular disease, and diabetes. These diseases may in turn relate to musculoskeletal disease and impair driving ability.

In the next 20 years, research will produce published scientific evidence that addresses possible interactions between fitness, exercise, and healthy lifestyles and long-term driver health, mortality, fatigue, and driving performance. Such research should generate testable interventions. The immediate problem is to collect health and wellness baseline data, and this action needs to be taken rapidly over the next 5 to 10 years. Baseline research could lead to interventions that will actually improve health and wellness.

It is also important to begin conducting experimental studies as opposed to some of the quasi-experimental designs. An important focus for future research should include nonfatal injuries, particularly musculoskeletal disorders. Trips and falls related to entering and leaving the vehicle are probably an important cause of driver injury, their need for health care, lost work time, and insurance and worker compensation costs. Research into work-related musculoskeletal disorders is a rapidly evolving field in which the interaction of various risk factors is being investigated.

There are inherent difficulties in conducting research that evalutes intervention. It is difficult to demonstrate scientifically the absence of an effect, such as a reduction in illness or injury, and even more difficult to prove that such an effect is causally linked to an intervention. Research partnerships between federal agencies, academic institutions, and industry stakeholders should address these complex relationships and develop and maintain a knowledge base on truck and bus driver health and wellness. Wellness interventions should be scientifically evaluated and the results made available quickly.

In the next 5 years the immediate research goal is to obtain reliable baseline data and understand factors that influence risk. On the basis of the status of current efforts, this goal seems attainable. The overall goal of relevant occupational health and safety research will be to improve and preserve the total health and wellness of employees in commercial truck and bus work. Safety, injury prevention, and health and wellness research may have important implications for preventing crashes. It may be assumed that healthier drivers are at the least more alert. It could also be the case that effectively addressing driver quality-of-life issues may lead to improvements in driver recruitment and retention.

Recommendation 4(a)

Research should be conducted on the prevalence and nature of factors contributing to driver occupational injuries and illnesses that are unrelated to crashes.

Recommendation 4(b)

The relationship between health and wellness and driver performance should be measured, individual and corporate benefits associated with healthy lifestyles quantified, and a regulatory framework, working environment, and incentives that promote healthier lifestyles created.

Recommendation 4(c)

Current medical requirements should be examined and updated, including a review of the effects of prescription and over-the-counter medications on driver performance.

5. Workforce Composition, Skills, and Training

Freight volume will double over the next 10 to 20 years, and trucks will carry a disproportionate share of the increase. Conference presenters pointed out that the future truck and bus workforce will be increasingly diverse with a large influx of women and minorities. The workforce is aging; the average age of a union driver is 54. Currently more than half of all truck drivers are 35- to 54-year-old white men. That cohort is shrinking and will continue to shrink over the next 10 years.

By the time younger drivers comply with most company and insurance requirements, they are 25 years old and in many cases are past the point of making career choices. Consequently, many entering the profession have burned out in other careers or have been displaced from other careers. The latter are a potential source for new drivers; however, this strategy will work only in certain specific fields.

Large trucks and motor coaches, like their four-wheeled siblings, are becoming high-tech, for better and worse. Many beneficial features are present in the latest technological interfaces finding their way into use on road vehicles; however, because the industry that designs, builds, and markets this technology is not driven primarily by safety but by sales and marketing, new technologies that have the potential to affect the driver's task adversely or to make it more difficult will increasingly be introduced into the marketplace.

Recruiting and training driver replacements is a growing and continuing challenge. Alternative training models will need to be developed and tested over the next 5 years with a variety of techniques, such as simulator and computer-based training, distance education, and other technologies. Simulation in particular may hold promise for younger people, who are accustomed to working with computers and gaming technology.

To some extent, driver recruitment, training, and retention issues are market driven; however, identifying effective methods for recruiting, training, and retaining healthy and safe drivers can be expected to produce significant safety gains.

Recommendation 5(a)

The relative effects of different types of training (simulator, computer simulation, long-distance, and on-the-road programs) on subsequent safety records, including commercial vehicle traffic and regulatory violations and crashes, should be quantified.

Recommendation 5(b)

A research program should be developed to study changes in workforce composition and their impact on driver recruitment, training, and retention.

Recommendation 5(c)

The effects of different work and rest schedules, methods of pay, type of carrier, carrier practices, and job benefits on the degree of workforce turnover and quality of new drivers should be studied.

6. Vehicle Design and Technology

It was explained during the conference that a group called the 21st Century Truck Partnership has already been established. Its members include truck, engine, and hybrid system manufacturers working in concert with federal government agencies, including the U.S. Departments of Transportation, Energy, and Defense and the Environmental Protection Agency. Its purpose is to improve safety and fuel efficiency while maintaining the planned emissions reductions. Projects already have been designed in the areas of fuel efficiency, safety, and hybrid vehicles. The partnership specifically has agreed to work toward the following objectives:

- Improved braking,
- Reduced stopping distance,
- Reduced heavy-vehicle rollover,
- Development and implementation of driver aid systems to promote safe following distance and in-lane tracking,
- Identification and implementation of systems that provide 360-degree visibility, and
- Improved truck tire performance.

This initiative demonstrates the importance of focusing attention on crash avoidance. Research to improve the design and the performance characteristics of the vehicle is expected to provide sufficient warning and reaction time for the driver to avoid or mitigate a potentially hazardous situation.

The research must not only improve the crash avoidance characteristics of vehicles and equipment but also steer clear of contributing to driver distraction. Head-up displays and other technology should be carefully evaluated to determine how driver workload is affected and whether the equipment might contribute to driver distraction and potential crashes.

Safety systems must be cost-effective and enhance productivity. Original equipment manufacturers and others are driven by "customer pull," and the customers are sensitive to the return on investment. Therefore, it is critically important that safety improvements be rigorously evaluated and that they demonstrate a positive return on investment within a relatively brief period of time, for example, 1 year to 18 months. Otherwise, many, if not most, customers simply will not purchase the equipment. Where safety technologies are proved to have a safety benefit, regulation should be considered since carrier benefits may be far less than societal benefits. FMCSA should investigate incentives and other means to encourage the use and evaluation of promising technologies.

Recommendation 6(a)

Methods and tools should be developed to assess drivers' situational awareness of events inside and outside the commercial motor vehicle and to provide driver feedback on potentially hazardous situations without causing cognitive overload.

Recommendation 6(b)

Studies should be conducted to quantify the return on investment and operational utility of safety-related technologies with specific attention focused on multifunctional systems.

7. Roadway Design and Operations

The conference discussion on roadway design and operations focused on three primary topics: the relationship between facility design and safety, increasing congestion, and alternative road-financing strategies.

Research shows that different roadway classifications perform differently in terms of safety. The lowest crash rates on the roadway systems are on limited-access highways, for example, freeways and toll roads. Higher crash rates occur on multilane nonfreeways where direct access is permitted, which include multilane divided and undivided highways. The highest crash rates occur on two-lane highways. Across this mix of highway types, crash rates differ by at least a factor of 3 or 4 between typical rural two-lane highways and rural freeways. Many of the lower class of roads were not built to accommodate either the volume of traffic or the size of heavy vehicles. The data show that these roads are particularly dangerous for trucks as well as other vehicles.

By 2025, congestion will certainly increase, perhaps dramatically because economic activity and the population will increase, but the road system will increase little, if at all. The lack of new capacity may have an important effect on truck safety. For one thing, trucks may divert to local, less congested roadways, but these roads are also inherently less safe. Conventional wisdom holds that when the road is congested, it is less safe. However, studies have produced inconsistent and conflicting results. Some believe that congestion may have a positive effect on safety in some cases because traffic moves more slowly; hence, the crashes are not as severe. The relationship of congestion to safety is complex and not well defined.

Many conference attendees noted that the Highway Trust Fund no longer provides adequate resources for building and maintaining the roadways. Consequently, an extensive discussion of alternative road-financing options is under way and will continue in the upcoming years. There is talk about moving away from fuel taxes and toward tolls to finance new roads and road expansion projects. These trends may produce some unintended consequences for safety.

If commercial motor vehicles are diverted from a limited-access highway to a conventional highway, either to avoid congestion or to avoid tolls, it is clear that collision frequencies will increase; collision severity may also increase, although that is less well quantified. Research clearly shows that roads with direct access and at-grade intersections experience higher crash rates.

Recommendation 7(a)

The safety implications of alternative roadway designs and operations should be examined.

Recommendation 7(b)

Driver, vehicle, and roadway safety performance requirements should be researched, and driver safety performance standards should be developed for the operation of larger, heavier vehicles.

8. Liability and Acceptance of New Technology

Onboard recorders and other technologies collect data that are sensitive in terms of such aspects as proprietary information, driver behavior, and vehicle performance. Issues abound regarding the data in terms of ownership, access, and the purposes for which it can be analyzed and used. Particularly relevant are the liability issues associated with using the data to show fault on the part of the carrier, driver, vehicle, or all three. However, the data can also be used in a variety of ways to improve safety, for example, to identify high-risk drivers. Technology is a two-edged sword. It provides data that may improve safety, but the same data can be used against a carrier for litigation purposes.

According to the conference presenters, many motor carrier companies do not understand the extent to which safety affects the bottom line. Although the larger truckload carriers will invest in technology, the smaller carriers will probably not unless mandated by law or regulation. Smaller less-than-truckload carriers tend to move from terminal to terminal, so there is no real need to communicate with the truck on the road. They will not see a benefit in using new technology. In any event all commercial vehicle companies will be leery of any technology that could bring them harm. Therefore, incentives should be considered for using data recorders to improve the data used for identifying crash causation factors.

Recommendation 8(a)

The liability issues associated with onboard electronic data recorders and other safety-related technologies should be researched and documented and methods identified for managing liability risk.

Recommendation 8(b)

Best practices for collecting, managing, analyzing, and protecting data that hold promise for improving safety should be researched and developed.

Introduction to Thinking About the Future

Stephen Millett, a futurist with Battelle Memorial Institute, steered the conference participants into the year 2025 and challenged them to remain in that frame of reference for the duration of the conference. He began by suggesting that all persons will regularly work 12-hour days and nights and pointed out that the conference agenda matched the future in that respect. He explained the nature of futuring and the tools used to conduct this work, suggested some trends and characteristics that may affect truck and bus safety, and warned against thinking in ways that can result in missed or incorrect future scenarios.

Futuring Defined

"Futuring" is the systematic process of thinking about the future and identifying emerging opportunities and threats. Futuring supports decision making and investments in the present that will influence a desired outcome in the future through an analytic process that focuses on external factors as opposed to internal corporate cultures. Focusing on the future and planning desired outcome scenarios helps to gain some degree of control over future conditions, events, and issues.

Futuring encompasses two important factors: (*a*) change will be uneven since current trends may not continue and (*b*) some things may, in fact, stay the same even though there is a propensity to think everything will be different.

To think clearly about the future, operational considerations must be suspended. In the future, people will be using tools and thinking in ways and perspectives that are impossible to consider in the current environment.

Methods and Tools

Many tools support thinking about the future. Trend analysis takes into account future economic conditions, demographic characteristics and shifts, consumer needs, choices and behaviors, and technological developments. Methods and tools that support thinking about the future include thought leader conferences, such as the current conference; expert focus groups; e-surveys; modeling; and simulations. Trend analysis captures continuity, but thought leaders capture discontinuity.

Future Characteristics Affecting Truck and Bus Safety

Thinking about the future of safety requires a focus on at least three aspects: operators and passengers, vehicles, and the environment. All three are integral not only to ensuring safety improvements but also to creating a future in which operators and passengers travel safely, the investment in vehicles is safeguarded, and the roadways are better at accommodating large vehicles and enhanced technologies.

Millett's future scenario for truck and bus safety involves the following characteristics:

- The definition of safety will change from simply being the prevention of death and injury to include a demand for more security.
- The population is aging and older citizens experience functional deficits as the aging process takes it toll. These declines will have significant consequences for both the safety and the mobility of older persons.
- Concern for and increased control of the environment to address global warming and other considerations will be advanced. Environmental matters will go beyond air quality and affect the components that make up quality-of-life issues.
- Greater linkage will occur between all modes of travel and will include goods movement. Systems will be more defined by who uses them for what purposes, and the outcomes will be measured in terms of value (value mapping). For example, in the 1950s and 1960s, vehicles were characterized by widely diverse styles and images. By the 1970s, more value was placed on energy efficiency and safety; hence, cars became more similar in design and functionality. The 21st century brought about a heightened concern for safety and security.
- According to futurists, the next frontier is likely to focus on increased confidence and peace of mind.

Forecasting Weaknesses

Futuring often produces a mix of both correct and incorrect scenarios because some events do not occur. Weaknesses to consider in futuring include the following:

- Sins of omission: information is not taken into account that is unknown and ignored;
- Recentness effect: scenarios are ignored or unknown because of the tendency to focus on recent events;
- Personal biases: individuals are either too optimistic (wishful thinking) or too pessimistic (doom and gloom);
- Multiple-trend analysis: multiple trends are not integrated into net assessments;
- Alternative futures: alternatives are not considered; and
- Getting only the basic story right: subtlety and details are lacking.

Problem Assessment

Michael Belzer, *Wayne State University*
Donald Osterberg, *Schneider National, Inc.*
Alan Pisarski, *Consultant*
Kenneth Campbell, *Oak Ridge National Laboratory*
Forrest Council, *University of North Carolina Highway Safety Research Center*
Tom Corsi, *University of Maryland*
John Berry, *FedEx Freight*
John H. Siebert, *Owner-Operator Independent Drivers Association Foundation*
Clyde Hart, Jr., *American Bus Association*
H. Douglas Robertson, *University of North Carolina Highway Safety Research Center, Moderator*

Participants in the conference brought with them an understanding of the historical crash experience of heavy trucks and buses. Although historical crash data were not presented or reviewed at the conference, a brief review of such data may be helpful in setting the context for the discussion summaries that follow. In 2003, medium and heavy trucks and buses represented roughly 4% of the registered vehicles in the United States. Medium and heavy trucks were involved in about 4,700 fatal crashes (9%). At the same time, medium- and heavy-truck–occupant fatalities were underrepresented (2%) relative to their proportion of registered vehicles. These proportions have not changed dramatically for several years (National Safety Council 2004, 100–101).

H. Douglas Robertson

The first step in addressing future research needs in truck and bus safety is to identify the problem clearly. Asking the right questions is imperative for a full understanding of the critical issues. Many of the moderators, speakers, authors, provocateurs, and audience participants emphasized the current state of affairs, which served as a point of departure, and approached problem assessment from two perspectives: (*a*) freight and logistics and (*b*) safety and data. Some of their comments are outlined in the following paragraphs.

Reality Check

Michael Belzer

- Commercial motor vehicle drivers account for 15.5% of all workplace fatalities.
- On average truck drivers die about two decades earlier than the general population, at about age 56.
- Employed truck drivers die at nearly twice the rate as do owner–operators.
- Injury to muscles, ligaments, and organs is cumulative and difficult to link directly to specific driving tasks; therefore, drivers and society absorb these costs rather than carriers and shippers.
- The driver shortage will continue as drivers grow older and replacements are unavailable because of the nature of the work environment.

Donald Osterberg

- The trucking industry is designed to be loose, and many carriers have institutionalized "running loose," which implies among other things that they follow weak standards in terms of safety management.
- Trucking is still a low-margin, ultracompetitive industry.
- Industry self-regulation is unlikely.

- Current enforcement has shown limited effectiveness.
- Compliance standards reinforce the loose nature of the industry.

Future Scenario

Donald Osterberg

- Another event similar to the terrorist attacks of September 11, 2001, involving a commercial truck may fuel American isolationism and elicit an emotional response by legislators.
- Public safety advocacy groups may gain traction for increased regulation of commercial transportation.
- Unchecked by meaningful tort reform, risk exposure is prohibitively high for motor carriers.
- Industry consolidation is ongoing.
- Public opinion has changed; highway safety is a priority.
- Infrastructure investments have been inadequate to accommodate increased vehicle miles of travel (estimated to increase 60% to 70% by 2025). Highway congestion is problematic.
- Transportation workers are in critically short supply.

Alan Pisarski

- Society will be more affluent, and greater demand for goods and services will increase travel.
- People will continue to fear trucks, and there is always the possibility that society will demand limits on truck travel.
- Truck travel will increase at a more rapid rate than passenger vehicle travel.
- Toll roads will increase. The decisions regarding what roads will be tolled and who will pay will be contentious.
- The population will age, and many will have diminished functional capabilities, which will decrease their ability to interact safely with trucks.

Research Needs

Kenneth Campbell

Campbell's remarks focused on safety research rather than safety in general and included a discussion of current state-of-the-art research methods and potential benefits that are revolutionizing safety research. He said that accident data are a rather flawed measure of safety and that we may see other measures that are much more useful and informative.

During the 1970s and 1980s, research focused on severe injuries and fatalities because those were the consequences to be avoided. Relatively little use was made of roadway data, which were limited and uneven across the country. Consequently, little from that period is known about the differences among collision types in various environments such as intersections and rural two-lane roads.

The failure to focus on noninjury collisions left a wide gap in the methodology in terms of calculating the probability of injury. Instrumented vehicle studies are offered as the solution to overcoming this weakness in research methods to allow the adoption of a precollision event methodology using multivariant models. A relevant analogy would be nuclear reactor safety research, which focuses on events before an accident because it is unacceptable to wait for a meltdown and then study the outcome. Highway safety research has generally focused, however, on the study of crashes and their circumstances.

The revolution in collision risk research uses instrumented vehicles for conducting multivariate analyses, including roadway characteristics and weather conditions, to identify and quantify risk factors. A promising area of study involves near collisions or critical incidents. The end result theoretically is quantification of the entire safety risk, which would allow comparisons of various routes, schedules, and other factors.

Campbell also supports black boxes on trucks, again to enrich the data for conducting prevention research. Finally, he cautioned against gathering data that are not collected for a specific purpose. From a research as well as a liability perspective, having data that are not useful presents a number of potential, tangential problems.

Commentary

Forrest Council

Many of Council's comments were taken from the Future Strategic Highway Research Plan, which suggests a similar revolution for collision avoidance in passenger cars. The potential, however, may be greater for heavy-truck applications than it is for passenger vehicles because heavy trucks are not included in the current F-SHRP plan. This lack may produce a gap in the results.

Panel Discussion

Tom Corsi, John Berry, John H. Siebert, and Clyde Hart, Jr.

Future Scenario

- Problems will center on people rather than hardware assets (vehicles and roadways). There will be a shortage of drivers and the industry will become more predatory (Berry).

- Truck and bus drivers are aging, and they experience the same functional declines as do other drivers as they age. The average age of truck and bus drivers today is 49 (Siebert).
- Increasing driver safety depends only in part on the truck and bus driver; focusing on passenger vehicle drivers is equally important. Improving their driving behavior is crucial for protecting the security of heavy-vehicle drivers. The industry will adopt technologies that improve safety (Siebert).

Research Needs

The following research needs were identified by panelists:

- Performance measures and standards in lieu of prescriptive hour-of-service regulations related to truck and bus safety (Siebert).
- Operational and administrative aspects of trucking companies with good safety ratings to determine what components promote safety (Corsi).
- Real estimates of capacity in terms of goods movement including the extent to which heavy vehicles travel empty or under capacity (Siebert).
- Intermodalism as it relates to buses in the context of an aging society, for example, the role of buses in enabling access not only to the bus but to events as well. This research implies addressing the safety and security of the pedestrian environment, for example, sidewalks and bus shelters (Hart).

Policies and Procedures

- Effective safety practices depend on buy-in by individuals. The current focus to achieve the desired behavior is on punishment. Future practice needs to identify incentives for ensuring long-term behavior change (Corsi and Siebert).
- The focus should be on creating driver conditions that induce safety behaviors, for example, driving rested and alert. Current practice encourages driving while fatigued and other hazardous behaviors (Siebert).

Audience Participation

After the presentation and panel discussion, the audience was invited to ask questions. The following two were prompted by the discussion on problem assessment:

Question

What are the costs of putting the technology, such as onboard recorders, on trucks?

Answer

The larger issue is dealing with the effects of technology itself on driver behavior, but that is a nonissue because drivers quickly grow accustomed to the technology and ignore its presence. Cost is also a nonissue, less than $1,500 per unit.

Comment

At this cost, a company could become the safest in the country at about the same time it files for Chapter 11 bankruptcy (Osterberg).

Question

What metric should be used to establish rates?

Answer

There are many different ways to address the issue, for example, raw numbers and rates per vehicle miles of travel. Looking at any one measure draws an incomplete picture, but the per-mile measure becomes predominant when one is looking at infrastructure improvements (Robertson).

In the end, data collection is a serious issue. Vehicle miles traveled and other measures are “sick birds,” and exposure data are lacking. It will take a lot of money to solve the data collection problem, and there doesn’t seem to be much forward movement on the issue (Pisarski).

Reference

National Safety Council. 2004. *Injury Facts,* 2004 ed. Itasca, Ill.

Human Performance and Behavior

Richard Hanowski, *Virginia Tech Transportation Institute*
Jeffrey S. Hickman, *Virginia Tech Transportation Institute*
Azim Eskandarian, *George Washington University*
Forrest Council, *University of North Carolina Highway Safety Research Center*
David Dinges, *University of Pennsylvania School of Medicine*
Gerald Krueger, *Wexford Group International*
Anne T. McCartt, *Insurance Institute for Highway Safety, Moderator*

There is a widespread industry perception that a small percentage of drivers is responsible for a disproportionate share of accidents. Empirical evidence supports this perception, and a large number of variables are individually associated with heightened risk. The variables studied include the following:

- Driver demographics;
- Driver behavioral history, for example, distress due to marital or financial issues;
- Driver physical and medical characteristics;
- Driver performance capabilities, for example, vision and reaction time;
- Driver personality, for example, aggressiveness;
- Driver off-duty behaviors;
- Carrier operation and management practices;
- Driving actions and behaviors;
- Vehicle factors; and
- Driving situational factors.[1]

However, the way these driver characteristics, vehicles, and the environment interact and under what circumstances they contribute to increased risk have not been studied and are not well understood. Furthermore, it is not known whether these characteristics are persistent and enduring traits or are transient. One method for studying these issues is through assessment under naturalistic driving conditions using onboard monitoring (OBSM) devices.

[1] For a full explanation of the characteristics, see Jeffrey Hickman's paper at the end of this chapter.

Research Needs

- Validate prior research findings indicating differential driver risk;
- Determine how enduring these differences are across time;
- Profile individual differences within a group of drivers and relate these differences to safety outcomes, such as crashes;
- Assess the efficacy of various driver selection instruments;
- Verify that differences in fatigue susceptibility are long-term personal traits;
- Document and disseminate the best driver management practices for use by carrier safety managers;
- Develop onboard safety monitoring devices that record a variety of safety-related driving behaviors;
- Improve driver training programs; and
- Conduct an industry pilot test of behavioral safety management techniques, perhaps enhanced by the use of OBSM devices.

Commentary

Richard Hanowski

Traditional crash database analysis provides important information about crash circumstances such as vehicle and environmental factors, but information about driver behavior before the crash is limited when traditional database approaches are used. Naturalistic studies are important for understanding driver performance error. Instrumentation of vehicles also allows feedback to educate the driver on a range of issues. The theory is that driver feedback mechanisms may eliminate the need for hours-of-service rules.

Naturalistic driving studies are a way to understand more about crashes that remain unreported because of damage thresholds and other reasons. Figure 1 shows the wide variation in results from the use of different research methods. (The definition of a crash varied widely in these studies.)

When the percentage of crashes involving driver distraction was estimated by using crash data, a rate of 25% was found. However, using instrumented vehicles, the researchers found a rate of 78%. This finding means that in 78% of the crashes, drivers were distracted by something and looked away from the road at a critical moment before the crash. Additional evidence has been found with respect to cell phone use. A study based on crash data estimated that 1.5% of crashes were associated with cell phone use. The naturalistic driving study showed a rate of 8%.

Statement

A national repository of naturalistic driving data should be created so that all the data from all studies can be combined and reanalyzed to answer more questions. The repository should be accessible to the scientific community, just as the Fatal Accident Reporting System and other databases are now.

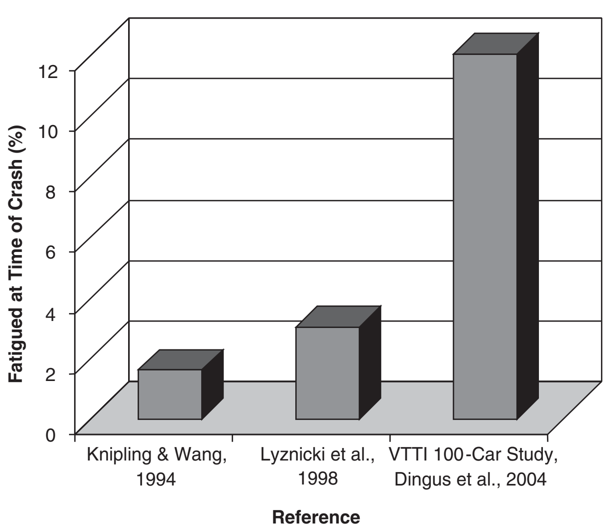

FIGURE 1 Research results on fatigue at time of crash.

Panel Discussion

Azim Eskandarian, Forrest Council, David Dinges, and Gerald Krueger

Future Scenario

- Many technologies to assist driver performance already exist, for example, in-vehicle information systems, advanced navigation systems, road and surface data, antilock brakes, cruise control, adaptive or intelligent cruise control, electronic stability systems, and active suspension. The future will include advanced driver assistance systems, such as hazard situation awareness and warning, and active vehicle control systems, such as brake and steering assistance, to prevent crashes due to lane departures and rollovers (Eskandarian).
- These advanced systems will assist the driver under low-visibility and negative road surface conditions and will ultimately help the drivers to avoid collisions (Eskandarian).
- Development and implementation of the technology will come slowly or not at all if the drivers do not accept, trust, and believe in the technologies (Eskandarian and Dinges).
- Research on driver assistance and vehicle control will be difficult because of the variance among drivers (Eskandarian).
- The future will see more trucks on the road 24 hours a day, 7 days a week (Dinges).

Research Needs

- Truck driver training to reduce backing, rear-end, right- and left-turn, and sideswipe crashes (Council).
- Car-driver training to reduce intersection angle and turning crashes and head-on crashes (Council).
- Behavior research on correcting driver inattention and unsafe speeds (Council).
- Development of Intelligent Vehicle Initiative technologies for passenger vehicles and trucks such as intersection gap warning and other collision avoidance technology (Council).
- Modification of freight delivery systems to separate cars and trucks, such as truck-only lanes or separate facilities for passenger vehicles and trucks (Dinges, Council, and several presenters).
- Modification of truck design and onboard technology to control speed, reduce rear-end collisions, and so forth (Council).

- A large-scale study to identify what factors are most salient to the amount of sleep drivers obtain on workdays and nonworkdays (Dinges).
- Differential vulnerability to sleep loss and adverse effects of night shift work (Dinges).
- The impact on alertness of loading and unloading freight (Krueger).
- A "readiness to perform" test for fatigue together with guidelines for drivers and management describing appropriate countermeasures (Dinges).
- The effects on alertness of prescription, over-the-counter, and other drugs and provision of the results to drivers (Krueger).
- Medical model to ensure that drivers are aware that sleep reduction affects length of life and other variables (Dinges).
- High driver turnover and strategies for managing it (Krueger).
- Effects of increasing racial and ethnic diversity in the industry (audience).

Comment

Before data gathering and research are conducted, three questions should be asked: (*a*) If we find the answers, will it make any difference; that is, is there anything we can do with the information? (*b*) If we find the answers, will the payoff be worth the effort? (*c*) Are research priorities directed by consideration of the impact on reducing harm or by what is easiest to accomplish (Council)?

Policies and Procedures

- Use simulators to periodically train or retrain drivers and teach them fuel-saving measures and other techniques at the same time (Krueger).
- Measure and use differences in circadian rhythm physiology to assign driver schedules and routes (Krueger).
- Provide training on fatigue and sleep apnea management and document the resulting changes in management policies and practices (Krueger).

Comment

Safe operating behavior in both drivers and companies should be rewarded, and driver sensitivities to behavior-monitoring devices should be recognized. Truck drivers are not inferior human beings and deserve civil rights protection and respect (Dinges).

References

Dingus, T. A., S. G. Klauer, V. L. Neale, A. Peterson, S. E. Lee, J. Sufweejs, M. A. Perez, J. Hankey, D. Ramsey, S. Gupta, C. Bueher, Z. R. Doerzaph, and J. Jermeland. 2004. *The 100-Car Naturalistic Driving Study. Phase II. Results of the 100-Car Field Experiment.*

Knipling, R. R., and J.-S. Wang. 1994. Crashes and Fatalities Related to Driver Dowsiness/Fatigue. *Research Note,* November.

Lyznicki, J. M., et al. Sleepiness, Driving and Motor Vehicle Crashes. *Journal of the American Medical Association,* Vol. 279, pp. 1908–1913.

High-Risk Commercial Motor Vehicle Drivers and Differential Crash Risk

Future Directions

Jeffrey S. Hickman

Recent studies by Lancaster and Ward (2002) and by Dewer and Olson (2002) have shown large differences in safety risk among individual commercial motor vehicle (CMV) drivers. Similarly, a TRB-sponsored synthesis study (Knipling et al. 2004) of individual differences in risk among CMV drivers found that a relatively small percentage of CMV drivers are associated with a significant and inordinate percentage of the overall motor carrier crash risk. The finding of differential crash risk among CMV drivers along many safety-related personal dimensions actually presents a huge opportunity to the trucking industry and government safety officials. If 15% of the drivers represent 50% of the crash risk, efforts directed at those 15% of drivers could yield significant safety benefits. Currently, kernels of knowledge suggest that certain factors are associated with high-risk driving. However, no comprehensive model quantifies the relative weights of individual factors or elucidates how these factors interact with each other. Further, no one study has included all these factors, nor have they been studied under naturalistic driving conditions. It is certainly possible that some unknown determinant is responsible for high-risk driving, and thus a naturalistic driving study seems most appropriate to determine this knowledge. This paper highlights key findings from the Knipling et al. (2004) synthesis report, as well as future research directions to reduce the high-risk driver problem in truck and bus safety and thereby achieve significant reductions in overall fleet and industry crash risk.

At any given time a multitude of interacting factors influence crash involvement, including fatigue-related factors (such as amount of prior sleep, time of day, and hours of driving) and nonfatigue situational stressors (such as pressure to deliver on time or recent events causing anger or anxiety). The driver is also operating a vehicle on a roadway under varying environmental conditions (such as weather and the actions of other motorists). All these can become major crash factors (Craft 2004; Treat et al. 1979). Figure 2 shows some of the predominant interacting factors that are likely to affect crash involvement. Commercial motor vehicle

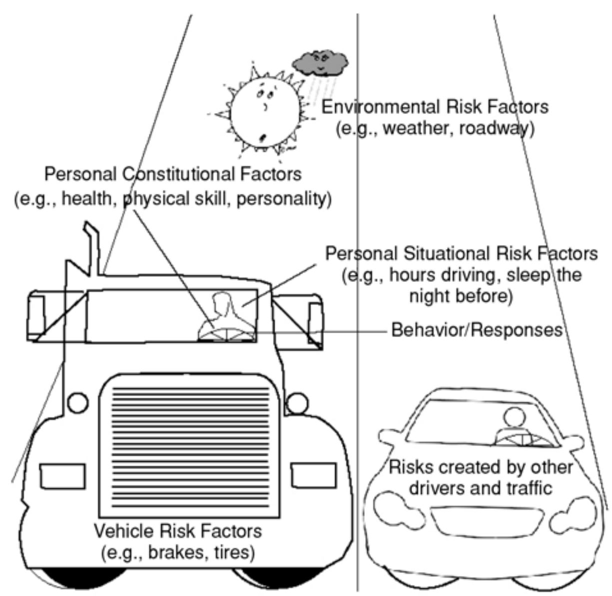

FIGURE 2 Major interacting factors affecting crash involvement of commercial drivers.

(CMV) driver behavior is likely to be a product of all these interacting factors. However, the primary aim of this paper is to focus on personal "constitutional" risk factors, that is, relatively enduring characteristics such as health, physical skills, and some personality traits.

The notion that some people are characteristically more inclined to have accidents than others has been referred to as accident proneness. The concept was first proposed by Greenwood and Woods (1919). The idea spawned much research, and many studies have been conducted on the subject since Greenwood and Wood's seminal study. When Greenwood and Woods analyzed the accident records of similarly exposed and experienced munitions workers in Britain, they found that a small percentage of the workers accounted for the majority of accidents.

It certainly appears that individual differences in personality and performance predispose some people to increased crash risk. Driver errors can be violations of rules, mistakes of judgment, inattention errors, or inexperience errors. Common driver errors resulting in crashes include recognition errors (failure to perceive a crash threat) and decision errors (risky driving behavior such as tailgating or poor decision making in dynamic traffic situations, such as trying to cross a stream of traffic) (Knipling et al. 2004). When the concept of accident proneness was first proposed, it generated enormous interest because of its practical implications. If CMV fleets could identify certain traits or behaviors of CMV drivers who were more likely to be involved in crashes (i.e., are high risk), they could be removed or intervened upon, and thereby future crashes and their associated injuries could be prevented.

EVIDENCE OF HIGH-RISK CMV DRIVERS

The study by Knipling et al. (2004) surveyed fleet safety managers and other CMV safety experts regarding high-risk CMV drivers and effective safety management techniques. The study also reviewed concepts of driver risk, factors related to driver risk, and fleet operations safety methods for addressing that risk. Perhaps the most fundamental question about high-risk CMV drivers is whether the problem is genuine and significant and not just an artifact of chance or factors uncontrollable by CMV drivers and their fleets. The majority of both respondent groups believed the worst 10% to 15% of drivers were associated with 30% to 50% or more of fleet crash risk. Further, about two-thirds of both respondent groups believed there was a strong tendency for individual differences in crash risk to be consistent and enduring from year to year.

Empirical data partially corroborate these views held by fleet safety managers and other CMV safety experts. A study sponsored by the Federal Motor Carrier Safety Administration (FMCSA) and conducted by Hanowski et al. (2000) observed 42 instrumented local and short-haul trucks that drove a total of 28,000 vehicle-mi. The study identified 249 critical incidents. Of these, 77 were primarily related to the behaviors of truck drivers. Common critical incidents included running red lights or crossing traffic with insufficient gaps (i.e., the approaching vehicles were too close for safe crossing). The 42 truck drivers were responsible for 77 critical incidents in 1,376 hours of driving.

Figure 3 shows the frequency of critical incidents per hour among the 42 drivers. As can be seen, six drivers had rates of critical incidents per hour greater than 0.15. These six drivers drove 12% of the total driving hours in the study but were responsible for 38% of all truck driver critical incidents (29 of 77). In contrast, 25 of the "best" drivers (the first two bars in Figure 3) drove 63% of the hours but were responsible for only 16% of the critical incidents. Figure 4 illustrates the exposure-risk relationship for the "worst" and "best" drivers in the Hanowski et al. (2000) local and short-haul study.

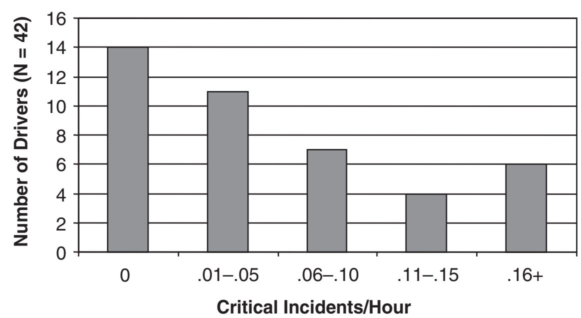

FIGURE 3 Frequency distribution of critical incident rate of local and short-haul truck drivers.

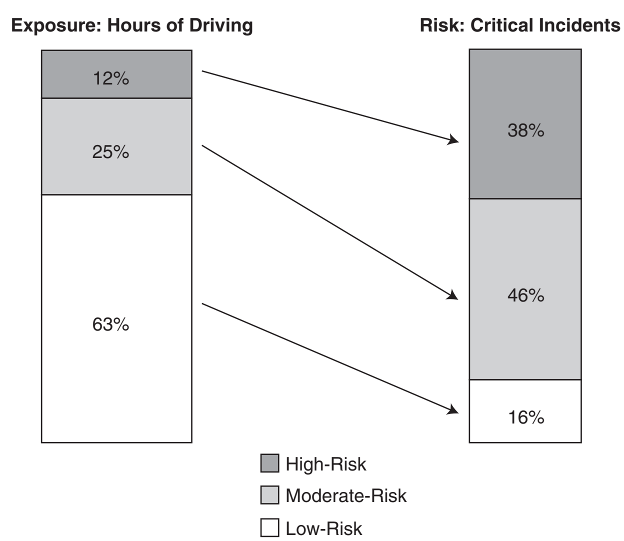

FIGURE 4 Relationship between exposure and critical incidents for three groups of drivers (Hanowski et al. 2003).

Most CMV drivers are both conscientious and safe, as evidenced by their generally lower crash and traffic violation rates compared with those of the general population of drivers and the fact that most two-vehicle crashes involving commercial vehicles are precipitated by the other vehicle (Craft and Blower 2003, 2004). Nevertheless, there is a widespread industry belief (Knipling et al. 2004) and empirical evidence (Hanowski et al. 2000) that a relatively small percentage of CMV drivers are associated with a significant and inordinate percentage of the overall motor carrier crash risk.

Factors Related to CMV Driver Risk

Driver Demographics

Age

Age has been shown to be one of the strongest factors affecting crash involvement in the general population (NHTSA 2000). However, these statistics were related to all drivers, commercial plus noncommercial. Regarding CMV drivers, those aged 25 or younger constituted 6.9% of the large-truck drivers involved in fatal crashes, 11.3% of those involved in injury crashes, and 13.8% of those involved in property-damage-only crashes in 2001 (FMCSA 2003). These statistics are hard to evaluate because the relative mileage exposure of young commercial drivers is not known. More definitive evidence was reported by Blower (1996), who found that young truck drivers (18 to 21 years old) had moving violation rates that were twice as high as those of middle-aged drivers (30 to 49 years old). A caveat to this study finding was that younger truck drivers tend to be hired by smaller, shorter-haul companies and are more likely to drive large single-unit (straight) trucks than their older peers (Blower 1996; Corsi and Barnard 2003). Of course, age is ever changing and is not a permanent trait, but it is a long-term trait that changes slowly. It is one of the strongest predictors of CMV driver risk (Hanowski et al. 2000).

Gender

Women constitute a small percentage of CMV drivers. In 2001, female CMV drivers represented 2.6% of fatal large-truck crashes, 4.5% of injury crashes, and 6% of property-damage-only crashes (FMCSA 2003). When Singh (2003) studied driver attributes in rear-end crash involvement, both young men and women aged 18 to 24 were more likely than older drivers to be involved in rear-end crashes. Both young men and women had about the same risk of involvement in the struck-vehicle role. However, for the striking-vehicle role, young men had about a 50% higher involvement risk than did young women. Although men have been historically more likely than women to engage in speeding, the gap between women and men has closed in recent years (Laapotti et al. 2003).

Driver Behavior History

Life Stressors

Stress is generally seen as a human response to an aversive or threatening situation. Distress arises from a judgment that demands exceed resources. Although stress is beneficial to performance, distress adversely affects performance. Stress alone does not adversely affect performance, but rather how a person appraises and copes with a stressful situation determines how stress affects behavior (Zuckerman 1999).

Brown and Bohnert (1968) reported that 80% of drivers involved in fatal crashes, but only 18% of controls, were under serious distress involving interpersonal, marital, vocational, or financial issues before the crash. McMurray (1970) found divorce to be a significant predictor of crash risk. In his study of 410 drivers involved in divorce proceedings, they had twice as many crashes during the year of their divorce than during the 7 previous years. This rate was even higher for the period 6 months before and after the divorce. These studies highlight the need for future research directed at assessing the adverse effects of stressful life events in CMV crashes. In particular, it would be helpful to tease out the causal relationships among personality factors, life stresses, and driving behaviors.

Driving Under the Influence

Federal law requires all motor carrier fleets to have active drug and alcohol testing programs. CMV driver alcohol use is infrequent, especially when compared with alcohol use while driving among noncommercial drivers. In fact, only 0.2% of commercial driver's license (CDL) holders tested positive for alcohol use, and 1.3% tested positive for controlled substances in 1999 (FMCSA 2001). In 2001, alcohol use on the part of CMV drivers was involved in 2% of fatal crashes, 1% of injury crashes, and less than 0.5% of property-damage-only crashes (NHTSA 2002). In a preliminary report on 210 crashes of light and heavy vehicles from the Federal Motor Carrier Safety Administration (FMCSA)–National Highway Traffic Safety Administration (NHTSA) Large Truck Crash Causation Study, Craft (2004) indicated that none of these 210 crashes involved alcohol or illegal drug use by the heavy-vehicle drivers. However, 11% of the light-vehicle drivers were under the influence of alcohol and

9% had used illegal drugs. These statistics indicate that CMV driver alcohol and illegal drug use is not a major factor in crashes. Nevertheless, any commercial driver identified as an alcohol or drug abuser should be considered a high-risk driver.

Prior Violation and Crash Involvement

It has long been known that prior crash rate is a strong predictor of future crash involvement and the driver's role (e.g., at fault versus not at fault). Using a sample of more than 200,000 (mostly noncommercial) drivers in Kentucky, Chandraratna and Stamatiadis (2004) were able to use past data on driver crash involvement and violations to predict future crash involvement with 88% accuracy by using a logistic regression model. Miller and Schuster (1983) followed 2,283 drivers in California and Iowa for 10 to 18 years and found that traffic violations were a better predictor than crashes of future crashes. Their results indicate that violation behavior is more stable over time than crashes and thereby a better predictor of crashes than crashes themselves.

Current FMCSA systems for prioritizing vehicles and drivers for inspection are based on the motor carrier's safety record, not on the safety record of individual drivers. Efforts are under way, however, to develop metrics and protocols for making inspection selection more specific to individual drivers (Lantz et al. 2004). This is an expected enhancement to be made to existing inspection selection systems in the coming years and is consistent with the evidence that safety risk varies significantly among CMV drivers.

Driving Actions and Behaviors

The survey by Knipling et al. (2003) of fleet safety managers and CMV safety experts found that aggressive or risky driving was rated as the No. 1 and No. 3 problem affecting CMV safety, respectively. Since many vehicle crashes and their associated injuries are the result of risky driving behaviors, such as speeding, improper following distance, and driving without a safety belt, reducing the risky driving behaviors of CMV drivers should result in huge safety benefits.

In 1997, 21% of all fatal truck crashes involved speeding (Office of Motor Carrier Safety 2004). When Stuster (1999) reviewed collision reports involving large trucks from seven different states, he found that speeding was the most frequently cited infraction. Section 392.16 of the Federal Motor Carrier Safety Regulations requires commercial drivers to wear safety belts while driving. Nevertheless, 311 of 588 fatally injured large-truck drivers in 2002 were not wearing safety belts and 134 of fatally injured drivers were ejected from the vehicle (FMCSA web page: www.fmcsa.dot.gov/safetybelt). A recent study by FMCSA showed that safety belt usage among CMV drivers was 48% compared with the national average of 79% among passenger vehicle occupants (U.S. Department of Transportation 2003). Further, Lancaster and Ward (2002) indicated that driver nonbelt use is associated with a variety of other risky driving behaviors, such as speeding, short headways (tailgating), alcohol use, red light running, more previous traffic violations, and sensation seeking.

Driving While Fatigued

Drivers who are sleep deprived have been shown to have significant deficits in vigilance and other cognitive abilities related to driving. For example, in a driver fatigue study with 80 long-haul CMV drivers, Wylie et al. (1996) found that 4.9% of the sampled video segments during the 4,000 h of driving were scored as drowsy on the basis of reviewers' assessments. One of the more interesting findings from the study was the individual differences in the incidence of drowsiness among the drivers. Twenty-nine of the drivers (36%) were never judged drowsy, and 11 of the drivers (14%) were responsible for 54% of all drowsiness episodes observed in the study. Similarly, an on-road naturalistic driving study by Hanowski et al. (2000) found that local and short-haul drivers reporting poor quality and quantity of sleep (as measured by self-reports and Actigraph) were found to be at fault significantly more often than drivers who self-reported good sleep. Van Dongen et al. (2004) found that there were stable interindividual differences in response to sleep deprivation on a variety of performance tests. These and other studies support the notion that large individual differences in fatigue susceptibility exist and that much of the difference reflects long-term personal constitutional differences. The physiological nature of these differences and how they interact with situational factors and short-term differences are unknown.

Driver Physical and Medical Characteristics

Sleep Apnea

Sleep apnea is a breathing disorder characterized by brief interruptions of breathing during sleep. Sleep apnea has been shown to increase the likelihood of being involved in vehicular crashes from two- to sixfold in the general population. It has been estimated that 4% of middle-aged male CMV drivers have some form of sleep apnea (Young et al. 1993). Pack et al. (2002) found that CMV drivers with some form of sleep apnea were more likely than other CMV drivers without the condition to exhibit deficits in vigilance and various sensory-motor tasks.

Narcolepsy

Narcolepsy is principally characterized by a permanent and overwhelming feeling of sleepiness and fatigue (http://www-med.stanford.edu/school/ Psychiatry/narcolepsy). Laboratory studies have found that subjects with narcolepsy were more likely than controls to hit a higher percentage of obstacles while performing on a simulator (Findley et al. 1995) and performed worse on a tracking error task during a simulated driving task compared with a control group (George et al. 1996). Moreover, Aldrich (1989) found that people with sleep disorders, primarily narcolepsy and sleep apnea, had the highest sleep-related crash rates.

Diabetes

Diabetes is of concern because individuals with diabetes may experience periods of hypoglycemia when they are treated with insulin. Hypoglycemia can alter judgment and perception and can even lead to a loss of consciousness while driving. In a cohort study of CMV drivers, Laberge-Nadeau et al. (1996) found that permit holders for single-unit trucks who were diabetic without complications and not using insulin had an increased crash risk of 1.68 when compared with healthy permit 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.

Driver Personality Correlates

Impulsivity

A variety of personality traits have been shown to affect vehicle crash risk. For example, impulsivity is characterized by behavioral instability and an inability to control impulses. Jonah (1997) found correlations between sensation-seeking and risky driving behaviors such as speeding, frequent lane changes, alcohol use, and failure to wear safety belts. Similarly, Rimmo (2002) noted that sensation seeking is strongly associated with misbehaviors (violations of rules) but only weakly associated with driving errors (e.g., failure to see another vehicle). In the study by Knipling et al. (2004), the personality factor “impatient and impulsive” was one of the highest-rated individual risk factors.

Social Maladjustment

Social maladjustment has also been shown to affect crash risk adversely. People are often considered socially maladapted if they have a general tendency to disregard laws and rules. South African bus drivers with repeated crashes were described by Shaw and Sichel (1961, 1971) as selfish, self-centered, overconfident, resentful and bitter, intolerant, and having antisocial attitudes and criminal tendencies.

Introversion–Extroversion

Introversion is defined as a person’s preference to attend to his or her inner world of experience with an emphasis on reflective, introspective thinking. Conversely, extroversion is defined as a person’s preference for attending to the outer world of objective events with an emphasis on active involvement in the environment. Introverted individuals place more value on being in control of their actions and would therefore tend to be more vigilant (Keehn 1961). Fine (1963) found that drivers with high extroversion scores were disproportionably more likely to be involved in traffic crashes. This finding was later supported by Smith and Kirkham (1981).

Locus of Control

The locus-of-control personality construct differentiates individuals with an internal or external locus of control (Rotter 1966). An individual with an internal locus of control is defined as someone who believes that he or she has the power to achieve mastery over life events. Conversely, an individual with an external locus of control has the belief that one’s efforts to effect change are useless. Jones and Foreman (1984) classified bus driver applicants with two or more moving violations into a high-risk group and those with no moving violations into a low-risk group. Of those in the high-risk group, 79% scored high on external locus of control versus only 31% of the low-risk group.

Driver Sensory-Motor Performance

As a dynamic sensory-motor task, driving performance is obviously affected by physical abilities (Dewer 2002). If physical prowess were the primary factor influencing crash involvement, teenagers and young adults would be the safest drivers. A 1998 study by the Trucking Research Institute and InterScience America found that age alone was not a reliable predictor of driving performance. This study found wide individual variation within and across age groups. Using an interactive commercial truck driving simulator, the study showed that the most predictive abilities (related to performance deterioration) were depth perception, useful field of view, field independence or dependence, attention sharing, and range of motion.

Summary

A variety of factors influence CMV driver risk. Few studies have attempted to integrate all the interacting factors (e.g., personality, sensory-motor performance, driving behaviors, prior crash and violation rate) that may contribute to an increased risk of a crash and most studies fail to account for exposure. Last, most prior studies use self-reports of prior crashes or retrospective Department of Motor Vehicle records. These approaches have limited utility for three primary reasons: (*a*) self-reports are likely to be inaccurate, (*b*) people do not always report vehicle crashes, and (*c*) people fail to assess near crashes (which occur far more often than crashes).

Currently, kernels of knowledge exist that suggest certain factors associated with high-risk driving; however, a comprehensive model on how these factors interact with each other does not exist. Further, all of these factors have not been included in one study, nor have they been studied under naturalistic driving conditions. It is certainly possible that some unknown determinant is responsible for high-risk driving, and thus a naturalistic driving study seems most appropriate to determine this knowledge.

The finding of differential crash risk among CMV drivers along many safety-related personal dimensions presents an opportunity for the trucking industry and government safety officials. If 15% of the drivers represent 50% of the crash risk, efforts directed at those 15% of drivers could yield significant safety benefits. Improved safety selection procedures could ensure that many of the worst drivers are never hired. Improved safety management procedures and onboard safety monitoring (OBSM) devices could ensure that drivers performing high-risk driving behaviors are identified early so that effective behavioral interventions can be implemented.

Research and development opportunities that will address the problem of high-risk drivers include the following:

- Validating prior research findings indicating differential driver risk;
- Determining how enduring these differences are across time;
- Profiling individual differences within a group of drivers and relating these differences to safety outcomes (e.g., crashes);
- Assessing the efficacy of various driver selection instruments;
- Verifying that differences in fatigue susceptibility are long-term personal traits, identifying ways to assess the level of fatigue susceptibility, and determining the physiological basis of differential fatigue susceptibility;
- Documenting and disseminating the best driver management practices for use by carrier safety managers (for example, do safety incentive programs work equally well for high-risk, average-risk, and low-risk drivers?);
- Developing OBSM devices that can record a variety of safety-related driving behaviors and management protocols for the successful use of OBSM data for reducing at-risk driving behaviors and crash rates;
- Improving driver training programs, possibly used in conjunction with driving simulators; and
- Industry pilot testing of behavioral safety management techniques, perhaps enhanced by the use of OBSM devices, to reduce the risky driving behaviors of high-risk drivers.

References

Aldrich, M. 1989. Automobile Accidents in Patients with Sleep Disorders. *Sleep*, Vol. 12, No. 6, pp. 487–494.

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

Brown, S., and P. Bohnert. 1968. *Alcohol Safety Study: Drivers Who Die*. Baylor University College of Medicine, Waco, Tex.

Chandraratna, S., and M. Stamatiadis. 2004. Crash Involvement of Drivers with Multiple Crashes and Citations. Presented at the 83rd Annual Meeting of the Transportation Research Board, Washington, D.C., 2004.

Corsi, T. M., and R. F. Barnard. 2003. *A Survey About Safety Management Practices Among the Safest Motor Carriers*. University of Maryland, College Park.

Craft, R. January 2004. Large truck crash causation study. Presentation to FMCSA "Synergy in Partnerships" Workshop, *TRB Annual Meeting*.

Craft, R., and D. F. Blower. 2003. The Large Truck Crash Causation Study. Presented to the American Trucking Associations, September.

Craft, R., and D. F. Blower. 2004. The Large Truck Crash Causation Study. Presented at FMCSA R&T Stakeholder Forum, Arlington, Va., November 17.

Dewer, R. E. 2002. Individual Differences. In R. E. Dewer and P. L. Olson, *Human Factors in Traffic Safety*, Lawyers and Judges Publishing Co., Tucson, Ariz., Chapter 5.

Dewer, R. E., and P. L. Olson. 2002. *Human Factors in Traffic Safety.* Lawyers and Judges Publishing Co., Tucson, Ariz.

Findley, L. J., M. Unverzagt, R. Guchu, M. Fabrizio, J. Buckner, and P. Suratt. 1995. Vigilance and Automobile Accidents in Patients with Sleep Apnea or Narcolepsy. *Chest,* Vol. 108, Vol. 3, pp. 619–624.

Fine, B. J. 1963. Introversion-Extroversion and Motor Vehicle Driver Behavior. *Perceptual and Motor Skills,* Vol. 16, pp. 95–100.

FMCSA. 2001. *Drug and Alcohol Testing Survey—1999 Results.* Analysis Brief. Publication FMCSA-MCRT-01-008.

FMCSA. 2003. *Large Truck Crash Facts 2001*. FMCSA-RI-02-011.

George, C. F., A. C. Boudreau, and A. Smiley. 1996. Comparison of Simulated Driving Performance in Narcolepsy and Sleep Apnea Patients. *Sleep*; Vol. 19, pp. 711–717.

Greenwood, M., and H. M. Woods. 1919. *A Report on the Incidence of Industrial Accidents upon Individuals with Special Reference to Multiple Accidents*. In E. A. Haddon, R. J. Hanowski, W. W. Wierwille, S. A. Garness, and T. A. Dingus, *Impact of Local Short Haul Operations on Driver Fatigue,* Final Report DOT-MC-00-203, FMCSA, U.S. Department of Transportation, 2000.

Hanowski, R. J., et al. 2000. *Impact of Local/Short Haul Operations on Driver Fatigue: Final Project Report.* DOT-MC-00-203. Federal Motor Carrier Safety Administration.

Hanowski, R. J., et al. 2003. An On-Road Study to Investigate Fatigue in Local/Short Haul Trucking. *Ingenta,* Vol. 35, No. 2, pp. 153–160.

Jonah, B. A. 1997. Sensation Seeking and Risky Driving: A Review and Synthesis of the Literature. *Accident Analysis & Prevention*, Vol. 29, pp. 651–665.

Jones, J. W., and R. J. Foreman. 1984. *Relationship of the HFPSI Scores on a Fatality Injured Construction Worker*. Technical Report. St. Paul Companies, St. Paul, Minn.

Keehn, J. D. 1961. Accident Tendency, Avoidance Learning, and Perceptual Defense. *Australian Journal of Psychology*, Vol. 13, pp. 157–169.

Knipling, R. R., J. S. Hickman, and G. Bergoffen. 2003. *CTBSSP Synthesis 1: Effective Commercial Truck and Bus Safety Management Techniques*. Commercial Truck and Bus Synthesis Program, Project MC-02, TRB, National Research Council, Washington, D.C.

Knipling, R. R., L. N. Boyle, J. S. Hickman, J. S. York , C. Daecher, E. C. B. Olsen, and T. D. Prailey 2004. *CTBSSP Synthesis Report 4: Individual Differences and the "High-Risk" Commercial Driver*. Commercial Truck and Bus Synthesis Program. TRB, National Research Council, Washington, D.C. Available at http://trb.org/news/blurb_browse.asp?id=11.

Laapotti, S., E. Keskinen, and S. Rajalin. 2003. Comparison of Young Male and Female Drivers' Attitude and Self-Reported Traffic Behavior in Finland in 1978 and 2001. *Journal of Safety Research*, Vol. 34, pp. 579–587.

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

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

Lantz, B., J. Loftus, and T. Keane. Oct. 2004. Development and Implementation of a Driver Safety History Indicator into the Roadside Inspection Selection System. Presented at 11th World Congress on Intelligent Transport Systems, Nagoya, Aichi, Japan.

McMurray, L. 1970. Emotional Stress and Driving Performance: The Effect of Divorce. *Behavioral Research in Highway Safety*, Vol. 1, pp. 100–114.

Miller, T. M., and D. H. Schuster. 1983. Long Term Predictability of Driver Behavior. *Accident Analysis & Prevention*, Vol. 15, No. 1, pp. 11–22.

National Highway Traffic Safety Administration. 2000. *Traffic Safety Facts: Older Population*. Report DOT-HS-809-328. U.S. Department of Transportation.

National Highway Traffic Safety Administration. 2002. *Traffic Safety Facts 2001*. Report DOT-HS-809-484. U.S. Department of Transportation.

Office of Motor Carrier Safety. 2004. *Speeding-Related Multi-Vehicle Fatal Crashes Involving Large Trucks*. www.fmcsa.dot.gov/Pdfs/Ab00-004.pdf.

Pack, A. I., T. F. Dinges, and G. Maislin. May 2002. *A Study of the Prevalence of Sleep Apnea Among Commercial Truck Drivers*. FMCSA Report FMCSA-RT-02-030.d. Trucking Research Institute and University of Pennsylvania.

Rimmo, P. A. 2002. Aberrant Driving Behavior: Homogeneity of a Four-Factor Structure in Samples Differing in Age and Gender. *Ergonomics*, Vol. 45, No. 8, pp. 569–582.

Rotter, J. B. 1966. Generalized Expectancies for Internal Versus External Control of Reinforcement. *Psychological Monographs,* 80 (1 Whole No. 609).

Shaw, L., and H. S. Sichel. 1961. The Reduction of Traffic Accidents in a Transport Company by the Determination of the Accident Liability of Individual Drivers. *Traffic Safety Research Review*, Vol. 5, pp. 2–12.

Shaw, L., and H. S. Sichel. 1971. *Accident Proneness*. Pergamon Press, Oxford.

Singh, S. 2003. *Driver Attributes and Rear-End Crash Involvement Propensity*. NHTSA Report DOT-HS-809-540. U.S. Department of Transportation.

Smith, D. I., and R. W. Kirkham. 1981. Relationship Between Some Personality Characteristics and Driving Records. *British Journal of Social Psychology,* Vol. 20, pp. 229–231.

Stuster, J. 1999. *The Unsafe Driving Acts of Motorists in the Vicinity of Large Trucks*. FHWA Report DTF HGI-97-000090. U.S. Department of Transportation.

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

Trucking Research Institute and InterScience America. 1998. *Research to Enhance the Safe Driving Performance of Older Commercial Vehicle Drivers*. ATA Product Code CO936. FHWA, U.S. Department of Transportation.

U.S. Department of Transportation. June 2003. *National Occupant Protection Use Survey (NOPUS)*.

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

Wylie, C. D., T. Shultz, J. C. Miller, M. M. Mitler, and R. R. Mackie. Nov. 1996. *Commercial Motor Vehicle Driver Fatigue and Alertness Study: Project Report*. Essex Corporation. FHWA Report FHWA-MC-97-002. U.S. Department of Transportation.

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

Zuckerman, M. 1999. *Vulnerability to Psychopathology: A Biosocial Model*. American Psychological Association, Washington, D.C.

Enforcement, Compliance, and Security Management

S. J. Shaffer, *Batelle Memorial Institute*
D. M. Freund, *Federal Highway Administration*
L. W. Loy, *Federal Motor Carrier Safety Administration*
L. W. Minor, *Federal Motor Carrier Safety Administration*
John H. Siebert, *Owner-Operator Independent Drivers Association Foundation*
Donald Bridge, Jr., *Connecticut Department of Motor Vehicles*
William Mahorney, *American Bus Association*
Donald Osterberg, *Schneider National, Inc., Provocateur*
Ronald Hughes, *University of North Carolina Highway Safety Research Center*
Stephen Keppler, *Commercial Vehicle Safety Alliance*
Skip Yeakel, *Volvo Trucks North America*
Conal Deedy, *Volvo Technology of America*
Tom Moses, *Spill Center, Inc.*
Charles Carden, *North Carolina State Highway Patrol*
Stephen Campbell, *Commercial Vehicle Safety Alliance, Moderator*

Future Scenario

S. J. Shaffer and Ronald Hughes

- Freight volume will increase significantly by 2025.
- Many more trucks will be on the road, and they will probably be larger than current standards allow.
- Drivers with sufficient skills, training, certification, and licensing will be in ever-shorter supply.
- Competition, liability, and other issues will force carrier consolidation.
- There will be an increase in new entrants into the system.
- Capacity limitations will result in congestion.
- A public–private partnership system will be in place to ensure that all vehicles are inspected at least once a year.
- Roadside inspections will be viewed as spot checks to ensure that the system is working.
- Most inspections will take place using technology that does not impede mobility, for example, smart vehicles, vehicle–infrastructure integration, and telematics.

Donald Osterberg

- The year 2025 is but an eye blink; in the future, conditions will be more similar to those today than they are different. Never underestimate the power of the status quo.
- The goal of truck inspections, company audits, and enforcement initiatives is to eliminate crashes, fatalities, and injuries due to vehicle defects. Although no good data correctly estimate the size of the problem, by any estimation some proportion of truck-involved crashes is related to the condition of the vehicle.
- By 2025 there will not yet be a solution to wear, structural fatigue, or failure due to overloading. However, there will be more advanced means to detect and

predict some degradation failures due to safety-related items, such as those that are

–Subject to wear, including brakes, tires, and steering components;

–Subject to erosion, such as windshields and lamp lenses, which when micropitted or scratched result in reduced or obscured visibility, particularly at night;

–Needing adjustment, such as headlights, mirrors, and video and radar systems, which are expected to be prevalent on vehicles in 20 years;

–Subject to structural fatigue, such as wheels, bolts, suspension system components, and frame members; and

–Tensioners or tension monitors, which are used to secure cargo.

Current enforcement techniques are personnel- and time-intensive and provide a limited presence on the roads, which results in inspection of a small percentage of units. The focus is on the driver, the vehicle, and carrier compliance; the cargo is generally not examined. The current process impedes mobility and commerce. Regardless of how much enforcement takes place, ther link between compliance-driven enforcement activities and safety is unclear.

Ronald Hughes

- Technology integration:
  - –Wireless [satellite, cellular, wireless fidelity (WiFi), dedicated short-range communication (DSRC), etc.],
  - –"Open" modular vehicle architectures,
  - –Tracking,
  - –Automation to address inherent personnel limitations, and
  - –Intelligent system monitoring, messaging (alerts) based on exception reporting.
- Program integration [within the Federal Motor Carrier Safety Administration (FMCSA)}:
  - –Commercial Vehicle Information Systems and Networks (CVISN),
  - –Expanded CVISN,
  - –Performance and Registration Information Systems (PRISM),
  - –Vehicle Intelligent Infrastructure (VII), and
  - –Intelligent Vehicle Initiative (IVI).
- Functional integration:
  - –Compliance,
  - –Safety, and
  - –Security.
- Integration of agency mission and goals within U.S. Department of Transportation.

S. J. Shaffer

Inspection of all heavy vehicles on an annual basis using electronic data obtained from the vehicle, performance-based measurements, advanced measurement techniques, and visual inspections and video with image recognition.

Research Needs

S. J. Shaffer

- Safety item assessment:
  - –Effectiveness of different methods to assess the compliance of CMVs with the list of safety-critical items in use in the future,
  - –Components or signals to be required on all CMVs to facilitate electronic and performance-based compliance checks,
  - –A standardized protocol for performing self-diagnosis calculations and accessing these onboard electronic data,
  - –Extracting on-vehicle compliance information to determine the means for restricting inspector access to onboard diagnostic data that directly apply to compliance with safety regulations, and
  - –Sensors that can be retrofitted to address potential safety- and cost-effectiveness.
- Type and extent of infrastructure required to inspect every CMV on a regular basis, including facilities, certified inspectors, and compliance-check-friendly vehicles.
- Methods for certifying nongovernment inspectors.
- Architecture of the international database for vehicles and inspectors and privacy access requirements.
- Effectiveness of assessment techniques and methods for retrofitting older vehicles.
- Critical components related to the safe operation of heavy vehicles.
- Methods for identifying poor-quality and counterfeit parts.
- Methods for restricting inspector access to only those onboard diagnostic data of direct application to compliance with safety regulations.

Ronald Hughes

- Methods to ensure new entrant compliance with safety regulations.
- Methods for vehicle inspection that do not halt mobility and that protect law enforcement officers at the roadside.
- Techniques and technology for integrating safety and security requirements.

Commentary

Donald Osterberg

The provocateur posed a number of issues and near-term applications for consideration by the panel, the speakers, and the audience.

Near-Term Changes

- Surface transportation control will become much closer to the current air traffic control system.
- Regulation that prevents truck travel on weekends, as in Europe, may become prevalent (8% of cargo is hauled on weekends, but 14% of the accidents occur during that time frame).
- National standards for driver licensing and training will be developed.
- Prices on goods will increase to pay for safety.
- Government will provide tax breaks and other incentives to encourage safety training and similar programs.
- The focus on cargo theft will increase.
- People will be willing to pay more for the products that are brought to them by trucks when they understand the linkage between price and safety.
- A high priority in the industry is the development of nonshift technology. Automatic-shift transmissions will reduce driver task saturation, improve situational awareness, and have a positive effect on safety.
- Over-the-road expectations are unrealistic; for example, Schneider's drivers work on average 307 days a year, whereas their nondriving associates work about 230 days per year. This condition is unfair and will change.

Future Scenario

- The future may bring something like remotely controlled hover-trucks as an interim solution to crashes, congestion, environmental damage, and so on, but that will not occur by 2025.
- Supply chain compression will occur (manufacturer direct to store or user) because consumers are purchasing more goods online; hence, residential shipments and LTL volumes will increase.
- Smaller manufacturing facilities will be built closer to customer bases.
- Because of barriers to entry, fewer carriers will exist, with resulting industry consolidation.
- Shippers will own trailer pools, that is, neutral boxes. Carriers will provide only the power.
- The competition for workers will increase:
  - –Men between the ages of 35 and 54 constitute the current majority in the driver pool; their numbers will decrease by 3 million by 2014.
  - –The overall workforce growth rate will slow by 65% to 2012.
  - –The imbalance between capacity and demand will increase from a 20,000-driver shortfall to at least 120,000 by 2014.
  - –International worker immigration is complicated by tightening restrictions driven by security concerns.
  - –Higher wages and a reasonable balance between work and life away from the job will be required to attract drivers to the profession.
  - –Increased qualification rigor will force many workers into construction or other semiskilled jobs and away from trucking.
- Technology will help, but worker shortage will be the primary impetus for fundamental change in the trucking industry.
- Research will be required in many areas to help pave the way for enhanced safety.

Panel Discussion

John H. Siebert, Donald Bridge, Jr., and William Mahorney

The following key points were made:

- Increases in safety will bring trade-offs such as less efficient movement of goods. We need to be aware of that and determine how much safety we can afford (Siebert).
- The industry will support technology if it is accurate, reliable, necessary, and affordable (Mahorney).
- The emphasis on security will change the way we look at safety and blend the line between the two; hence, the elements subject to vehicle inspections will change (Bridge).
- Human factors issues and research involves drivers, shippers, buyers, carriers, and mechanics (Bridge and others).

Audience Discussion

The following key points were made:

- The relationship between vehicle inspection and crash risk is not known, and completed studies are dated. A new study needs to look at this issue and break it down by component, for example, the percentage of crashes that can actually be attributed to brake failure (Shaffer).
- By 2025, safety inspections and safety in general will be affected by introduction of new components into the vehicle.
- The often-quoted statistic that one in three vehicles inspected are put out of service is inaccurate and unfair

because it does not account for the biased vehicle inspection selection process.

- FMCSA should repeat the random roadside survey study to get better and more recent data on the actual condition of trucks on the road.
- Thought should be given to methods for managing the amount of data that is forthcoming.
- Two of three vehicles are not put out of service and may represent a large and expensive effort with little or no effect.

Research Required to Ensure Appropriate Maintenance and Compliance for Safe Operation of Commercial Motor Vehicles in 2025

S. J. Shaffer, D. M. Freund, L. W. Loy, and L. W. Minor

As 2025 approaches, highway safety will be influenced by a significant increase in vehicle kilometers traveled (VKT), compounded by increasing constraints on the ability to perform roadside safety compliance checks on all but a small fraction of CMVs operating in North America. This scenario will force the adoption of a new paradigm for ensuring proper maintenance, compliance inspections, and confirmatory performance-based measurements for maximizing safe CMV operation. Furthermore, a national or international tracking system will also be required. A system similar to that used in parts of the European Union (EU) will likely be adopted; annual (or more frequent, depending on the cargo transported) mandatory visual inspections are combined with vehicle performance assessments of specific systems, such as brakes and steering. Additional use of electronic data from sensors and onboard self-diagnostics will be used. A single government database, in which vehicle compliance and safety status can be accessed systemwide, will also be in use. In this scenario, the elimination of preventable vehicle defects as contributors to crashes can be approached. An increase of between 60% and 70% in the current number of CMVs is expected over the next 20 years. Clearly, some new form of government and private-sector partnership will need to provide an infrastructure that will ensure and track the proper performance of CMV safety systems, both within fleets and by enforcement agencies. Although new onboard diagnostic technologies will have been introduced to assist the driver, roadside inspector, and fleet safety manager in assessing CMV compliance with safety regulations, each technology may require a different approach. Research will be required initially to determine which technologies are worth a significant investment. Research will then be needed to develop the means to obtain, assess, and archive this information and then to share it with the appropriate parties. Example technologies requiring different approaches include onboard sensors and diagnostic software of braking systems, onboard data recorders, performance-based brake testers (PBBTs), and electronic log books. Each technology, whether mandated by government safety regulations for onboard diagnostic sensors or installed in an inspection–maintenance garage-type environment by the CMV fleet or by an enforcement agency, can have significant infrastructure and cost requirements. A shortage of personnel to conduct these safety inspections may also present a challenge. Research efforts in the area of enforcement, compliance, and carrier safety management will be required to address the following questions: What is the effectiveness of different systems used to assess the performance of CMV safety systems? What type of infrastructure is needed to achieve regular annual assessments of vehicle performance? How can such an infrastructure be achieved, in terms of a partnership between government and industry, and what is the return in terms of improved safety? Can large fleets be self-certifying under the right system? Could maintenance consortia be considered for small fleets? What is needed and how should a national or international tracking system be set up?

According to the U.S. Department of Transportation (DOT) Motor Carrier Management Information System (MCMIS) database, over the past 8 years approximately 33% of the roughly 600,000 combination CMVs pulled from the traffic stream and subjected to a Commercial Vehicle Safety Alliance (CVSA) Level 1 inspection were placed out of service (OOS) for mechanical defects. (A Level 1 inspection means that a certified inspector selects a vehicle from the traffic and examines evidence of the driver's qualifications such as CDL, medical examiner's certificate, record of duty status, hours of service, and vehicle pre-trip inspection report and a list of vehicle-based safety items such as brake system, coupling devices, exhaust system, frame, fuel system, turn signals, brake lamps, tail lamps, head lamps, suspension, tires, wheels, rims, hubs, and windshield wipers.) In comparison, the percentage of combination CMVs placed OOS is 20% for the roughly 3,300 Level 5 inspections performed annually over the same period. (A Level 5 inspection covers the same items as a Level 1 inspection, but the inspection is conducted without a driver present. Although they can be conducted anywhere, Level 5 inspections are usually conducted at the terminal of a fleet whose safety records are being audited during a compliance review.)

Because terminal inspections generally target fleets with poor safety ratings, it is clear that maintenance improves when a compliance inspection is planned and a vehicle is, in principle, prepared for it. If any vehicles are placed OOS during a preplanned inspection, this action indicates that maintenance personnel are not adequately trained to perform a self-inspection or that some of the vehicles were simply not brought to compliance standards before the inspection. CMV safety could be improved in the next 10 to 20 years if every vehicle were subjected to regular inspections by a qualified inspector and if appropriate corrective actions were taken before that vehicle went into service. The previously described inspections did not use any quantitative measurements of vehicle performance or other safety items, such as brake force measurements, headlamp aim and intensity, or windshield clarity. Compliance with these measurements is not mandatory and there are no current regulations enforcing such. Including additional quantitative safety-related inspection methods and vehicle compliance to these methods would no doubt further improve safety.

FHWA estimates indicate that the total VKT by heavy vehicles will increase by 60% to 70% by 2025. The number of CMVs is expected to roughly parallel the predicted increase in VKT. There are two major reasons for this prediction. Because of structural limitations of roads and bridges, gross vehicle weight (GVW) or gross axle weight (GAW) limits are likely to remain the same. Furthermore, the use of lightweight materials in vehicle construction is likely to have only a small influence on cargo-carrying capacity.

Need to Inspect Every CMV with Improved Tools

Reduction in Crashes and Fatalities

Although it is recognized that driver error is cited as a contributing factor in the majority of the nearly 5,000 CMV-related annual fatalities and 122,000 CMV-related annual injuries, it is clear that some of these fatalities and injuries resulted from a preventable mechanical defect or deficiency in a CMV's steering, brakes, suspension, tires, lighting, signaling, or cargo securement. The vast majority of those deficiencies might have been prevented through appropriate maintenance and safety regulation compliance. Without question, crashes and fatalities can be reduced if fit, alert, and well-trained drivers are operating CMVs free from mechanical defects and deficiencies. This discussion will only briefly address the driver fit-for-duty compliance verification and will primarily focus on elimination of mechanical defects or deficiencies.

Self-Assessing Vehicles and Advanced Compliance Inspection Facilities

To approach the elimination of preventable vehicle defects as contributors to crashes, it must be accepted that a combination of downloaded self-diagnostic or other onboard data, quantitative performance-based measurements, and visual observations must be performed regularly on every commercial vehicle, either by or under government supervision or by government-certified inspectors. Clearly this is a new paradigm compared with the current inspection climate, in which fewer than 10% of the in-service vehicles are inspected annually by a government-certified inspector at the roadside. This paper addresses the various elements of this new paradigm and indicates the areas where research is likely required. In some cases, the technology already exists, and the research would therefore be focused on the means of implementation.

Items Covered in Future Compliance Inspections

Research is required to refine and improve the list of items for which compliance is important to the operational safety of CMVs. Additional research will likely be required to address the growing concern about counterfeit or poor-quality replacement parts. When a postinstallation performance-based measurement is not possible, independent testing and a means to address the availability of replacement parts approved by original equipment manufacturers (OEMs) must be implemented.

Vehicle Wear Parts

In 20 years the problems of wear, structural fatigue, and failure due to overloading will not have been solved. The list of items for which regulations will exist and compliance will be required will still include components subject to mechanical degradation. The list of safety-related items will include the following:

- Wear, including brakes, tires, and steering components;
- Erosion, such as windshields and lamp lenses, which when micropitted or scratched result in reduced or obscured visibility, particularly at night;
- Adjustment, such as headlights, mirrors, and the video and radar systems expected to be prevalent on vehicles in 20 years; and
- Structural fatigue, such as wheels, bolts, suspension system components, and frame members.

The overall stopping and steering capability of the vehicle, if loaded beyond its gross or axle weight rating, should also be checked. Although the majority of these items are inspected today, the additional anticipated items inspected on future vehicles will require new methods. These methods are covered in the section on the means to assess safety items for compliance.

Vehicle Sensors and Electronics

In the next 10 to 20 years, the use of onboard sensors and self-diagnosing electronics will be common. These nonmechanical components and systems—such as antilock braking systems (ABS), automatic traction control (ATC), rollover warning and control (RAWC), lanekeeping, forward collision warning (FCW), adaptive cruise control (ACC), and electronically controlled braking systems (ECBS)—will likely be used for performing safety functions as well as for self-diagnosis of impending problems or degradation in performance. Many of these sensors and systems could be used to provide proactive self-diagnostic functions. For example, applied braking pressure could be compared with the CMV's deceleration. If the deceleration output measure is outside its operating threshold, the results could be used to alert the driver or to store a message for the maintenance mechanic. In addition, if performance drops to present minimum values for these status indicators, they could be flagged for future compliance inspection. Indications of air system irregularities, tire pressure problems, even trailer kingpin wear can be tracked and logged electronically.

Cargo Securement

In 20 years the loss of improperly secured cargo will likely continue to pose a hazard to other vehicles. Although this will still be a part of a compliance inspection, only the integrity of the attachment points can be checked on unladen vehicles inspected at a terminal facility. Other means will need to be developed for laden, in-service vehicles. One example might be self-checking cargo securement devices that incorporate built-in tension meters or vibration sensors.

Means to Assess Safety Items for Compliance

Inspecting every CMV on a regular basis requires a combination of techniques to maximize both efficiency and effectiveness. Research is required in the following areas:

- To determine the effectiveness of methods to assess the compliance of CMVs with the list of safety-critical items in use in the future;
- To identify the components or signals to be required on all CMVs to facilitate electronic and performance-based compliance checks;
- To develop a standardized protocol for both performing the calculations for self-diagnosis and accessing these onboard electronic data;
- For extracting on-vehicle compliance information, to determine the means to restrict inspector access to only those onboard diagnostic data that directly apply to compliance with safety regulations; and
- To retrofit sensors and address potential safety and cost-effectiveness of such retrofits.

Electronic Data from Vehicle

Electronic data will likely be the most efficient to obtain. Although some vehicles would be equipped with the means to transmit these data to a nearby receiver, others would likely have to access a physical connection. Today this would likely be the SAE J 1939 diagnostic port, but it could well be something different in 2025. On-the-road vehicles could transmit a variety of vehicle health signals while passing weigh stations or weigh-in-motion (WIM) devices. Some critical wear or maintenance and adjustment items, such as brakes, could be monitored any time the vehicle traveled past such a site. Type certification for testing and diagnostic devices to ensure consistent output will likely be needed.

For terminal-based or garage compliance checks, privacy concerns will be an issue when enforcement personnel's "readers" are physically connected to and accessing the vehicle's internal communication network. From the fleet's perspective, the concern would be whether access to other data would be possible and would lead to subsequent punitive actions. For example, it may be possible for an enforcement official to obtain the vehicle's previous maximum speed on a recent trip. Such information is available on some of today's vehicles. What should be done if evidence for an excessive speed is found? The inspection is, in principle, concerned only with ensuring that there are no mechanical defects or deficiencies. Although there may have been no safety issues whatsoever, with a speed of 130 km/h at the time under the circumstances, should a citation be given? Clearly, such privacy issues will need to be resolved for enforcement personnel to use the onboard diagnostics that will be available in the next 10 to 20 years. Research in this area is required.

Special Treatment of Older Vehicles

Although it is unlikely that all critical safety items could be assessed economically via onboard electronic means, in the next 10 to 20 years regulations might be in place to mandate that a minimum number of onboard self-diagnosed safety items be monitored and reported or available for downloading. However, it is conceivable that some vehicles on the road today or placed into service in the next 5 years will still be on the road in 10 to15 years. Certainly many of today's trailers could be still on the road in 2025. As such, if these vehicles are not exempted, the ability to retrofit the sensors and data processors to older vehicles for subsequent access by inspectors will be another area for research. Possible examples include electronic decelerometers, pressure transducers, stroke sensors, and brake lining thickness monitors.

Performance-Based Measurements

Many of today's inspection items are qualitative, surrogate measures for vehicle performance. Thus, the pass-or-fail criteria tend to be conservative. Expansion of current inspection items and additional methods will likely include performance-based measurements, the objectivity of which would lend them to more precise pass-or-fail criteria. It is likely that quantitative measurements will include the following performance-based measurements and checks:

- Brake force measurements: Performance-based brake testers (PBBTs) are in their infancy for enforcement use today, but they are widely used in Australia, Japan, and the EU. Such PBBT measurements provide quantitative evidence that a vehicle braking system provides adequate brake force per its design specifications. These PBBT measurements are complemented by a visual inspection.
- Steering component checks: Quantitative measurement of tie-rod play and steering lash will be made using computer-controlled, instrumented multidirectional sliding plates.
- Dynamic wheel and bearing checks: This equipment will be checked by lifting the axle and using devices that spin the tire to monitor play and drag.
- Tires: Tires will be checked either by the signal obtained from onboard pressure transducers or through ultrasonic pressure indicators. Tire case structural integrity and case and tread integrity could similarly be checked by using a nondestructive evaluation (NDE) technique of the future.
- Headlight aim and intensity checks: Checks will be conducted by using a lens and target device that ensures that the headlamp is properly aimed. The intensity is measured with a simple light meter device. These checks are critical to the safety of the CMV driver and possibly even more so to the drivers of other vehicles, particularly those in the oncoming direction.
- Windshield pitting and visibility: Performance will be assessed by using laser light transmittal devices. Such windshield quality performance measurement devices are currently under development and are candidates for use in future inspections to improve safety.

As noted, each of the foregoing methods will require a specialized piece of equipment, designed to quantify the performance of the relevant safety item on the vehicle. In some countries, such as Sweden, mandatory annual inspections are currently required. Every vehicle must visit a certified inspection station, which includes a PBBT and many of the other performance measurements in the inspection described earlier. Sweden's noncompliance rate and fatality rate per 1 million KMT are both lower than those in the United States.

Future innovative tools, with access to comprehensive databases and using computer-driven graphic displays, will permit original performance specifications to be readily available in easy-to-visualize means for both the mechanic and the inspector. Such tools will aid in identifying and quantifying degradation from original performance specifications. Research will be required to identify specifications for new and in-service components that could form the basis for performance-based measurements to include in the compliance review and user-friendly methods to make them available to the inspector.

Visual or Video with Image Recognition

Although brake design may migrate away from s-cam activated drum brakes in the next 20 years, it is conceivable that visual inspection of components, such as automatic brake adjusters and the condition of hoses or the remaining thickness of linings or drums, will still be required as part of compliance inspections. Video systems and image recognition software may play an increased role as inspector aids. Such systems would presumably alleviate the need for an inspector to climb underneath a vehicle in order to assess those components or items for which a performance-based measurement or an electronic assessment was not possible.

Infrastructure Required for Inspections

To this point the discussion has included only what specific systems would be included and what methods would be required to assess a vehicle for compliance with safety regulations. The greatest challenge to the elimination of fatalities and injuries resulting from a preventable mechanical defect or deficiency is the ability to conduct such inspections regularly on every commercial motor vehicle. This brings up the infrastructure. Although some information could be obtained from a transponder-activated download of certain transmitted signals, the type of complete inspection described earlier is not conducive to a conventional roadside inspection. Rather, a fixed facility would be required to provide the dedicated mechanical and electronic diagnostic equipment necessary to assess all safety-related items on the vehicle. The vehicle itself would incorporate refinements to allow it to fit seamlessly into the infrastructure through utilization of onboard sensors, diagnostics, and other aids in the compliance assessment. There are also some possibilities to make the vehicle more inspector friendly.

Research is required to determine the type and extent of infrastructure required to inspect every CMV on a regular basis, including facilities, certified inspectors, and compliance check–friendly vehicles. Research is also required to identify and determine how to implement certification of nongovernment inspectors.

Facilities

At first, one might think that putting in place the facilities and personnel required to inspect 12 million vehicles on an annual or more frequent basis would be cost prohibitive. However, with some moderately creative approaches, and a government–industry partnership, developing the facilities for such an inspection system is indeed possible. As a simple calculation to gauge the required infrastructure, it may be assumed that there are 12 million CMVs to be inspected in 2025. Further, it is expected that such facilities will include a combination of government inspection stations; large fleet in-house maintenance facilities ("certified" inspectors working with on-site government liaisons); private, government-certified, third-party shops to perform compliance inspections; and possibly industry consortia shops to accommodate small fleets and independent owner–operators. These smaller shops would also interact with government-certified inspectors and a government liaison.

To estimate the number of inspection sites required, a complete inspection, including all paperwork (it is nearly certain that all documentation will be entered, stored, and transmitted digitally) is assumed to take 60 min, and a facility has an average of five bays and works only 5 days a week at an efficiency of 75% (six inspections per bay per day). With these numbers, it is found that 1,600 facilities are required, an average of only 32 per state. If the construction of all new facilities were required to accommodate the compliance inspection of the future, an average of 1.6 facilities per state per year would have to be constructed over the next 20 years. If each facility cost $5 million, each state would require $8 million a year to put the infrastructure in place.

With a more efficient view a lower bound can be estimated in terms of facilities and expense, for example, 24-h shifts run 6 days a week. In this case, even with the same modest inspection efficiency of 75%, fewer than 450 facilities would be required, an average of only nine per state or one built in each state every 2 years. Clearly the infrastructure is feasible, although research would be required to determine the optimum distribution of such facilities so that it is proportional to the number of CMVs housed in a given geographic area. It would be ideal if no vehicle had to travel more than 30 to 45 min to get to a facility. Further, it is likely that many existing shops and current fleet facilities could be used for the inspections merely by installing the proper equipment.

For remote areas where the CMV population may be sparse, an alternative way to ensure that every vehicle could be checked might entail the use of portable inspection systems. Although the cost of such portable systems would likely be greater than that of a fixed facility, these would offer an advantage to those fleets and individual operators in areas distant from the fixed facilities. Alternatively, a consortium of small maintenance shops might arrange for portable testing devices to be transported to their facilities.

In all cases, someone other than the driver would likely do the compliance inspection. Upon bringing the vehicle in for inspection, in cases other than large fleet maintenance facilities, the driver could use the time for reading, exercise, catching up on e-mail, or enjoying recreational diversions (such as movies or video games) available at the inspection facility. The compliance inspection of 2025 would no longer be the adversarial "us versus them" scenario that it sometimes appears to be today but would be something every driver or vehicle owner looks forward to.

Certified Inspectors

The infrastructure situation seems quite tractable, but the issue is really that of compliance verification to the satisfaction of the government agency responsible for CMV safety, currently the FMCSA. With a calculation similar to that for the number of inspection facilities and assuming the need for three inspectors per bay per shift (a team of two with a third to allow for scheduling flexibility and rotation), conservatively about 4,800 government-certified inspectors would be required. In Sweden, 5 million vehicles per year are thoroughly inspected by 1,800 certified inspectors. However, the question exists whether the government should be in the business of performing all the inspections with government employees or whether third parties should be certified to do so. If the certification process is effective, the majority of the personnel and facilities may already be in place, and it would merely be a matter of equipping them with the proper tools.

Government Liaison Assigned to Fleet Facility

In the case of large fleets, many currently have above-average safety ratings, and they are well equipped to perform their own maintenance and compliance inspections. It might work best for these operations to have the appropriate number of on-site government liaisons at each facility to assist and supervise the fleet as needed. The FAA has implemented similar procedures in which government inspectors are stationed on site at airline maintenance and repair facilities.

Vehicle Standards and Best Practices for Components, Sensors, and Signals

To facilitate future compliance inspections, and in particular many of the future performance-based assessments, it is likely that some additional components will be required on future vehicles. Although this requirement might be viewed initially as a financial burden, fleets would ultimately reap the safety and cost benefits. A few examples are discussed next.

Pressure Ports for Air System Checks

When a vehicle's brake forces are measured with a PBBT, a considerable amount of additional diagnostic information is available if the application air pressure is also measured. Requiring a universal quick-release fitting on the distribution valve of tractors and trailers would allow the easy attachment of a pressure transducer to be used then in conjunction with the PBBT measurement. This would be particularly useful if fully "brake-by-wire" systems were in place in the future, in which case the control signal would no longer be pneumatic.

The future analogy, however, would be the requirement of access to the electronic brake control signal through the diagnostic data port or other connection to the brake system CPU.

J1939 or Successor

The compliance inspection could be greatly accelerated and much onboard diagnostic information could be obtained if access to a standardized data port were mandatory. Such data ports are likely to follow the protocol of today's SAE J1939, ISO 11992, or their successors. Clearly, as these data access ports and the information available through them evolve, so will the government and industry's need to work together to use them to improve vehicle maintenance and compliance inspection efficiency.

Tracking System for Vehicles and Inspectors

National or North American Database

Now that the items requiring compliance inspections and the requirements for infrastructure and personnel have been described, the means to keep track of both the vehicles and the inspectors must be considered. A national or international database will be in place as well as a system for immediate access to necessary information. All information related to vehicle inspections will be transmitted via the Internet with some data residing in secure locations and other data available to the public. For example (and not unlike today), a person can see the safety rating for a carrier but not information about specific drivers. Every vehicle, tracked by its vehicle identification number, will have a record of its past inspections, its most recent inspection, and the due date for its next inspection. This information will be available to the vehicle owner, fleet managers, vehicle driver, and government oversight agency representatives. Research is required to identify the architecture of this international database for vehicles and inspectors.

Vehicles

After notification of an upcoming inspection due date has been received via e-mail, all appointments for inspections will be scheduled over the Internet. Should an appointment not be scheduled or be missed, the database would notify the appropriate parties, including the vehicle owner, fleet manager, and most recent vehicle driver, and subsequent actions could range from daily e-mail reminders to fines to remote disabling of the vehicle (in principle).

Vehicles with continued records of good compliance would be rewarded with longer periods between oversight inspections. At the same time, vehicles with poor compliance would be encouraged to improve their vehicle safety through requirements for more frequent inspections. This system would readily optimize the interval on the basis of safety.

Inspectors

An identification number, in an analogous fashion, will track each inspector. The results and time required to complete every inspection would also go into the database. If these measures of an inspector's performance should degrade over time, as measured by a significant change in the average time it takes to complete an inspection or the average number of defects found on a vehicle, the system may flag this individual for further training, a meeting with a supervisor, or other actions. In this way, the uniformity and quality of the system would be maintained.

Summary

The paradigm for CMV maintenance and compliance with safety regulations in 20 years will depend more on onboard sensors, electronics, and self-diagnostics as well as an infrastructure developed to access these signals. However, the need for inspectors and facilities is also likely to increase, both to cover those items that cannot be assessed electronically and to accommodate the increased number of vehicles. The army of certified inspectors will be made up of both government and industry personnel, and the facilities will also likely be a mix of private government-certified shops and government-owned inspection stations. An international database will ensure that vehicles are regularly maintaining compliance with safety regulations and that certified inspectors are performing the inspections objectively. Research in many areas related to this future system will be required.

Context for Commercial Vehicle Enforcement Activity in 2020

Forecast of Future Directions in Truck Safety and Security

Ronald Hughes, Stephen Keppler, Skip Yeakel, Conal Deedy, Tom Moses, and Charlie Carden

Future research and technology needs for commercial motor vehicle enforcement are discussed within the context of the increasing emphasis on freight operations associated with multimodal, global, and supply chain management. Research is needed to exploit the application of current and future technologies capable of overcoming constraints associated with the continuation of traditional, labor-intensive enforcement methods, methods that significantly limit the spatial and temporal elements of enforcement effectiveness and capacity. Just as FHWA has recognized that it cannot build its way out of the growing congestion problem, neither can motor carrier enforcement hope to become more effective simply by adding more officers. CMV enforcement capabilities need to keep pace with technology-based modes of operation under development by the trucking industry. Commercial vehicle operations will become increasingly information-driven, and enforcement must be able to operate fully within such an information-based environment. More effective and more highly automated information screening methods need to be developed to detect anomalies in driver, vehicle, route, and load information streaming in from thousands of continuously tracked vehicles. It is likely that FMCSA as well as the Transportation Security Administration (TSA) and the Homeland Security Department will have to seek such expertise outside the current transportation community (e.g., from within the intelligence sector). Methods need to be developed to enable enforcement to preempt incidents having the potential to harm the public seriously or to cause disruption to critical infrastructure. Shorter incident response times are a necessary but are not a sufficient condition for deterrence. Inspection methods need to be developed to provide alternatives to a uniformed officer who must physically stop a vehicle to inspect it. Methods also need to be developed to enable a single officer to screen multiple vehicles effectively (passively as well as actively) as they pass in and out of the effective range of a wireless ability to interact with the truck's onboard systems. Finally, enforcement needs to work with the OEM community to develop systems that are self enforcing, that is, provide the system, its operator, or both with information that ensures safe operations. In addition, enforcement needs to develop improved methods of collaboration with the industry to the point where the industry is willing to share information voluntarily with the motor carrier enforcement community because of its belief that enforcement constitutes an effective partner in reducing the carrier's exposure to safety and security risks.

The safety and security of CMV operations are the major responsibilities of FMCSA, the Transportation Security Administration, and the states as well as professional organizations such as the CVSA, which work closely with FMCSA and TSA to develop effective program strategies in these areas. Within FMCSA, enforcement represents one of the chief strategies applied in an effort to reach the FMCSA 2008 strategic goal of 1.67 CMV-involved fatalities per 100 million CMV-miles traveled (DOT 2003).

Current CMV enforcement strategies focus predominantly on the conduct of the Standard North American Driver and Vehicle Inspection (Levels 1 to 6), size and weight efforts jointly administered by FHWA and the individual states, as well as compliance reviews and safety audits. Driver and vehicle inspections, whether conducted at static weigh stations, randomly on the side of the road, or in carrier facilities, are manpower and personnel intensive: manpower intensive in the sense of being extremely labor intensive and personnel intensive in terms of the specialized training required for their conduct.

As FMCSA looks toward 2020, thought needs to be given to the continued feasibility of whether traditional enforcement methods represent the most effective strategy for meeting long-term safety and security goals (FMCSA 2005; Cambridge Systematics 2005). At the same time that consideration is given to the continued feasibility of such manpower- and personnel-intensive operations, consideration must also be given to the role of technology in enhancing current effectiveness and extending its functional presence, both spatially and temporally.

The effectiveness of enforcement will also be a function of the context in which it operates. Any projection of future enforcement needs and capabilities must take into account the broader context of future freight demands (FHWA 2004), the role of freight management within a global supply chain, surface transportation infrastructure and its operation (Walton 2004; TRIP 2004), the continued development of new vehicle technologies (Intelligent Vehicle Initiative 2005; Sandberg 2003; *California Engineer* 2003; Society of Motor Manufacturers and Traders, Ltd. 2004), industry practices (Knipling et al. 2003), and the role of government (FMCSA 2005), as well as influences of the global labor market (National Intelligence Council 2004). Thus, although commercial vehicle enforcement per se remains the responsibility of FMCSA, its effectiveness will be determined in large part by factors outside the agency.

The following discussion is an attempt to address this broader context and its perceived impact on CMV enforcement practices in the time frame between the present and 2020. The comments presented here represent an attempt not to predict the future, but rather to formulate an effective context for thinking about the type or types of enforcement that will be both practical and effective in the future and what research needs are associated with getting to that point in time. The perception of future needs expressed in the following discussion may seem overly critical of FMCSA and imply that the agency should be doing things that currently lie beyond its assigned realm of responsibility as a modal administration within the U.S. DOT. Some suggestions might equally be directed toward DOT as a whole. To the extent that increased emphasis may be placed on multimodal issues of safety and security within the context of a global supply chain, any discussion of national freight 2020 is secondary to discussion of the same or similar issues on an international scale. The playing field is changing if for no other reason than that the origin and destination of goods being transported by U.S. commercial vehicles extend well beyond the U.S. borders.

Focus on Trucks

The following discussion focuses on the perception of the future research and technology (R&T) needs of trucks and does not address separately the R&T needs of motor coaches (Hoemann 2003). Motor coach safety concerns, unlike safety concerns for trucks, generally focus on passenger protection (improved design of window emergency exits, standards for stronger roofs, decreased the likelihood of being thrown from a seat or ejected when a bus sustains a front, side, or rear impact, etc.) versus concerns for the safety of those involved in collisions with buses. Such safety concerns from an R&T standpoint tend to be more within the domain of NHTSA or FTA even though FMCSA is responsible for motor coach safety per se. Buses used for school transportation and those used for public transit are outside the responsibility of the FMCSA.

The motor coach and truck R&T domains share similar program concerns (e.g., driver licensing and credentials, driver fatigue, and safety management). The security-generated R&T focus on motor coaches [generally since the terrorist attacks of September 11, 2001 (9/11)] has centered on the selective adoption of vehicle tracking systems, real-time communication with drivers, driver panic buttons, passenger and luggage screening, driver protection (from attack or highjacking), and passenger cabin surveillance. When such technologies have been implemented, they have generally been on a limited, pilot basis. Commercial vehicle enforcement efforts directed toward motor coaches consist primarily of driver and vehicle inspections, compliance reviews, and safety audits. Although motor coach safety will, in all likelihood, remain the responsibility of FMCSA, R&T efforts directed specifically toward motor coach (principally passenger) safety should be within the domain of NHTSA, FTA, or both. Therefore attention is turned now to the perceived future R&T needs for trucks.

Projections for 2020 call for a doubling of freight volumes, a 65% increase in domestic tonnage, and a doubling of international tonnage, with trucks carrying 75% of the tonnage (Walton 2004) (Figure 1). The transport of cargo by trucks is predicted to take place within a surface transportation environment characterized by a predicted 78% increase in vehicle traffic with increasing congestion and bottlenecks (Figure 2). Although the travel of combination trucks increased by 102% from 1980 to 2002, the total lane miles of public roads increased by only 4%, according to the Road Information Program (TRIP) (TRIP 2004) (Figure 3). FHWA estimates that the percentage of urban Interstates that

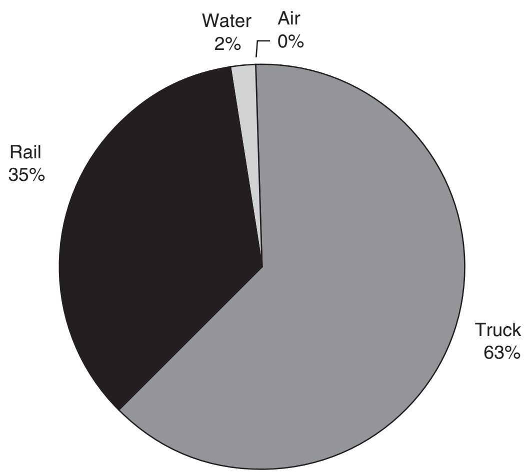

FIGURE 1 Modal share of anticipated growth to 2020 of U.S. traffic on a ton-mile basis (FHWA 2004).

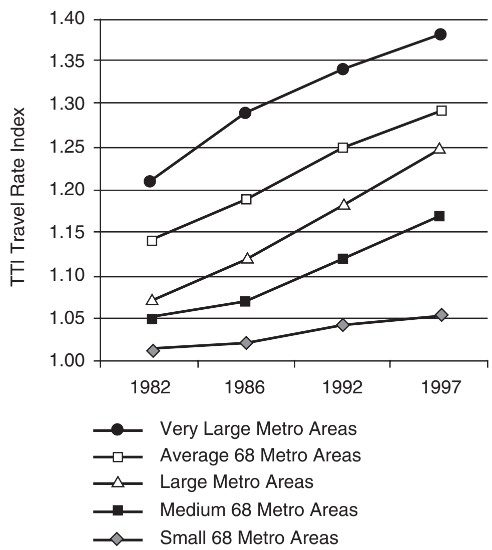

FIGURE 2 Travel rate congestion index (average percentage growth in peak period travel time compared with offpeak travel time in 68 large metropolitan areas was 81%) (FHWA 2004).

will carry 10,000 or more trucks per day will increase to 69% by 2020 compared with 27% in 1998 (TRIP 2004).

DOT for some time has recognized that it cannot hope to build its way out of the projected problem but rather that it needs to focus strongly on effective operations and in many instances (especially in terms of personal travel) on the way travel is conducted. The need for new roadway construction and improvements to existing roadways must keep pace with the projected increase in trucking. There is a need not only to develop infrastructure that keeps pace with the increasing geographic dispersion of the general population but also to develop and manage roads (and related concepts of operations) that are sufficient for the projected increase in commercial vehicle traffic.

New System Requirements Imposed by Security

With the increased focus on security since 9/11, it has become painfully obvious how difficult it is (and will become) to monitor not only the presence and movement of hazardous materials by truck but also the movement of hazardous and other materials from mode to mode within a global supply chain (Science Applications International Corporation 2003) (Figure 4). If it is currently not feasible with existing methods and levels of personnel to inspect physically more than 1% to 2% of all containers entering U.S. ports, how can effective monitoring, much less physical inspection, of the volume of cargo expected to enter the United States by 2020 be achieved?

Significant increases in cargo volume are problems not only at port facilities but also at border crossings. By 2020 the movement of goods from manufacturer to eventual end user will require a much more coordinated intermodal and interagency focus than currently exists. Information at all points in the supply chain will be at a premium. The means of collecting that information and dissemination of it in an effective and secure manner become key operational issues in a global freight management system (Figure 5).

FMCSA's focus on security must not be limited to providing safeguards against the potential use of commercial vehicles as weapons intended to inflict human death and suffering. The agency's security focus must also address the protection of critical infrastructure, such as critical transportation system infrastructure and facilities, traffic management centers, toll plazas, and inspection and size and weight facilities. As critical aspects of the surface transportation infrastructure become more controlled, breaches of security at such facilities can cause significant long-term as well as short-term disruption (Ham and Lockwood 2002; AASHTO 2003).

Need for Command, Control, Communications, and Intelligence

Although improving interagency coordination and cooperation will have its own challenges, perhaps the greater challenge will be to improve the efficiency of enforcement operations regarding both the time required to screen and inspect cargo and the personnel required to do so. The cargo security problem is not entirely solved by the ability to inspect goods at their port of entry. There will be an equal need to track and monitor cargo

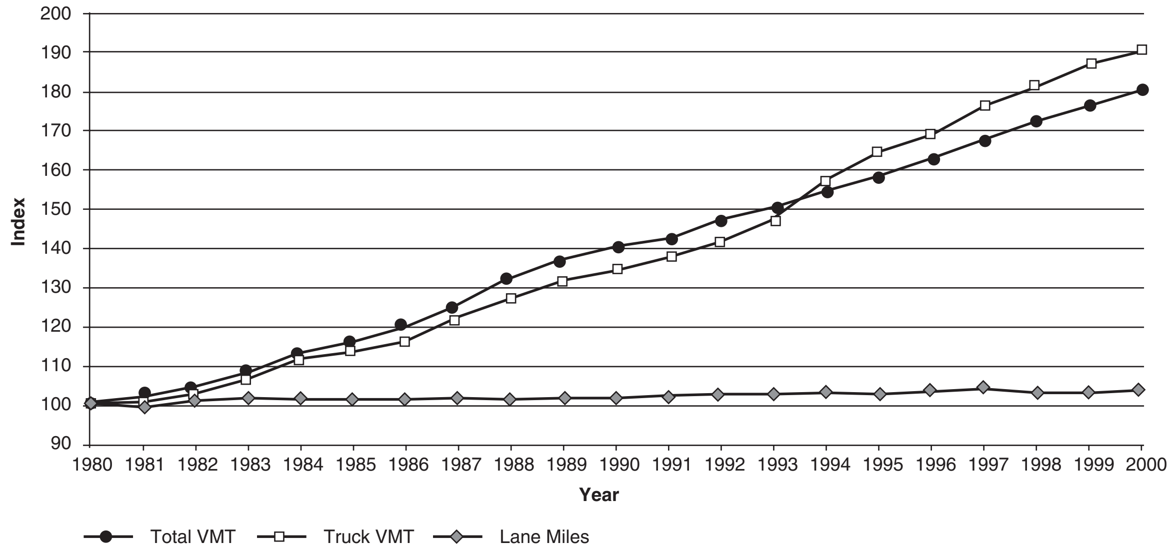

FIGURE 3 VMT and lane miles, 1980 to 2000 (FHWA 2004).

FIGURE 4 Inspection of cargo containers by U.S. Navy on board the container ship Ibn Al Haithan in the Persian Gulf on January 31, 2001. Courtesy of the Department of Defense; photo by Petty Officer 1st class Tina M. Ackerman, U.S. Navy (released).

FIGURE 5 Caltrans District 7 Traffic Management Center.

while en route. One example of such a capability is the Intelligent Road/Rail Information Server (IRRIS) (Figure 6) being developed for the military's Surface Deployment and Distribution Command, the mission of which is to aid the global deployability of U.S. armed forces and to manage, document, and synchronize the movement of cargoes by land and sea on a global basis. The goal of IRRIS is to provide a single point of interface for worldwide asset visibility and detailed infrastructure information (Geo-Decisions 2005).

Command, control, and communication systems (C^3 in military terminology) will increasingly characterize the commercial movement of goods, not only for secu-

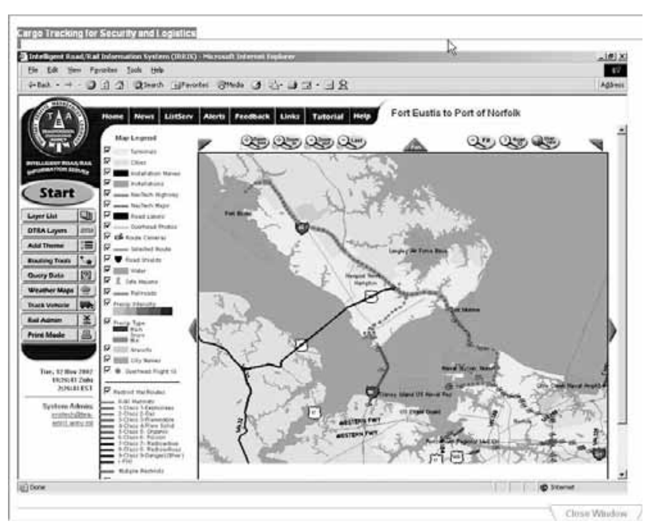

FIGURE 6 Example of IRRIS graphic user interface (http://www.geointelmag.com/geointellligence/article/article Detail.jps?id=79383).

rity purposes but also for efficiency gains associated with tighter control within an increasingly just-in-time marketplace. With an expected increased in the focus on security, one anticipates seeing a shift from C^3 to what the military and defense communities refer to as C^3I, or command, control, communications, and intelligence.

The recently conducted DOT Hazardous Materials Safety and Security Field Operational Test (FOT), in its effective demonstration of an event-driven Public Sector Reporting Center (PSRC), showed how the application of off-the-shelf technologies combined with modern communications technologies could significantly reduce response times to events (and more importantly to patterns of events) that might indicate the presence of a terrorist threat or, at a minimum, to conditions leading up to a potential hazardous materials (hazmat) incident. Figure 7 is an example of the approach used by Spill Center, Inc., in support of the hazmat Safety and Security FOT for generating an event-based off-route alert.

Although the PSRC concept implemented for the FOT might be called smart, it cannot at its current stage of application be called intelligent in the sense of being able to reliably distinguish a terrorist event or pattern of events from a nonterrorist occurrence. This is not a criticism of the methodology but rather a statement of the limited information available to the system and the sophistication of the current methodology used to process that information. The FOT system applications represented a quantum improvement in C^3 capabilities within the area of hazmat operations but have yet to add the "I" required for an effective C^3I application.

Security at the level of a global freight management system must have access not only to real-time cargo shipment information but also to manufacturer, shipper, carrier, and consignee information. Data archiving and data warehousing, once the focus of information and data-intensive intelligent transportation system traffic management centers, will become mainstream issues in freight management security systems. As in all information-driven systems, there will be issues regarding the proprietary nature of the information and the individuals who need to know. There remains much to be done before the trucking industry comes to see enforcement as a partner whose involvement can actually increase productivity.

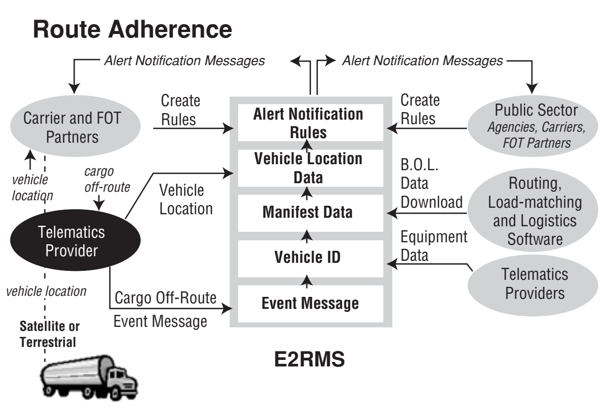

FIGURE 7 Approach used by Spill Center in implementing event-based off-route event message.

Dependence on Infrequent Information Snapshots

To the extent that the "I" will be dependent on the availability of additional sources of information and data, it would be logical to expect development efforts that seek to integrate the PSRC concept and FMCSA's notion of an expanded Commercial Vehicle Information Systems and Networks (CVISN) capability (Salazar 2004). CVISN, like the PSRC concept, is currently at the level of a simple C^3 capability, in essence a real-time look-up capability that, in the case of CVISN, looks up current information on a carrier's safety record, the carrier's compliance in terms of proper registrations, and similar information.

The limitation of CVISN is that conducting the check is currently limited to those occasions when a properly equipped (with transponder) vehicle passes under or by a reader at a fixed site such as a weigh station. Awareness of that vehicle's presence and operational status is limited to those brief points in time when the vehicle is in the physical proximity of the reader. If the vehicle goes off-route, if there is an indication of tampering, if there is a change in the authorized driver, or if there is a significant change in the equipment status of the vehicle or its load, the information goes undetected until the vehicle reaches the next CVISN reader. In most cases, currently no other opportunities can collect this information unless it is through a manual sighting report by an enforcement officer or via the transmission of those data to some roadside device.

Increasing Mobile Surveillance Capability of Enforcement

Commercial vehicle enforcement personnel cannot query a truck without having to stop the truck physically, an activity that is both dangerous and insufficient in terms of delay. Given the increased availability of secure, wireless communications, it should be possible for enforcement personnel to query a CMV while en route as the two vehicles pass within the range of their respective short-range communications systems capabilities. Such a mobile query capability would significantly increase the number of readers in the field; since it is mobile, it would disperse reader locations beyond the limited, and predictable, locations of readers at weigh stations, toll plazas, and other sites. An officer in the field could, for instance, query a passing commercial vehicle's onboard data recorder or electronic logbook for real-time driver hours-of-service information. And to the extent that enforcement could write to the vehicle's database, real-time out-of-service actions could also be attached electronically to that vehicle. Such a query might also be placed from the operator of a scale facility as the truck sits on the static scale.

Such a mobile (i.e., vehicle-to-vehicle) reader capability presumes an ability to communicate wirelessly (and in a secure environment) between CMVs as they move down the road and mobile enforcement resources in their immediate (short-range) vicinity. It presumes that the communication between the commercial vehicle and the enforcement vehicle could take place passively (i.e., without officer intervention) or under the control of the officer operating the vehicle. To the extent that the enforcement vehicle would function as a reader, one would also expect the enforcement vehicle to communicate with other system networks (e.g., CVISN) and to be able to conduct the same type of screening that would occur at a fixed or virtual weigh station.

The system would log the temporal (time) and spatial attributes (location) of these mobile interactions and could provide useful data on truck presence (e.g., for use in state fuel tax assessments).

Smart Roads: Fixed Points or Continuous Capabilities?

It seems reasonable to predict that the physical infrastructure (i.e., roads) would become smarter between now and 2020. Smart roads are currently smart only at fixed locations. To the extent that advanced freeway management systems rely on old-fashioned inductive loop detectors for their knowledge of traffic operations, their intelligence is limited to information on vehicle presence, vehicle class, and vehicle speed. There is no identification or logging of information on vehicle ownership, registration, whether the vehicle is stolen, or who is operating the vehicle. FMCSA, state divisions of motor vehicles, and others concerned with the real-time identification of motor vehicle users need to sponsor joint research and development efforts that will make roads smarter along their entire length, either through simple visual surveillance or through an ability to interact with the vehicles passing over them. That interaction might initially be as simple as the ability to read an electronic license plate and to access information stored in conjunction with a vehicle's registration.

By 2020 it appears that at least hazmat loads considered high risk, such as bulk petroleum, bulk explosives, and toxic inhalants, will be monitored continuously and their position as well as load status, status of driver and vehicle, and so forth will all be known on a real-time, or near real-time, basis. It also appears that carriers of such high-risk loads will be able to shut down those operations remotely when there is suspicion of wrongdoing or a potential harmful event. Such a prediction for the cases of hazmat operations seems relatively certain given the feasibility of current technology demonstrated in the DOT HazMat Safety and Security FOT and efforts under way within the TSA to develop a national hazmat tracking capability and alerting system. One cannot be as certain about conditions in 2020 for the nonhazmat element of the commercial vehicle fleet.

Where significant monetary and accountability issues are associated with unexpected disruptions to a carrier's operation, for example, theft of high-value goods or incentives associated with timely delivery, one can reasonably predict that tracking and surveillance technologies will be implemented. To the extent that theft or tampering may be a less pervasive event, those technologies may be adopted at a slower rate.

One area of truck activity lying outside a formal freight management system is the noncommercial (private) use of rental fleets, especially those that make vehicles available to the public with a minimum requirement of a current motor vehicle driver's license and some indication of an ability to pay. There are generally no verification of the intended use of such vehicles and, once the rental agreement is signed, no means of tracking their whereabouts until they are returned to the same or different rental location. As Global Positioning System hardware becomes smaller and smaller and is capable of being integrated into more and more products (e.g., cell phones, navigation systems), rental fleets may find that the costs associated with providing features like cell phones and simple navigation systems for user convenience can also provide an unobtrusive means for monitoring the location of their vehicles.

Trucks of the Future

Anticipated increases in the focus on operations within the data- and information-intensive environment of global freight management will require OEMs (such as Volvo Trucks North America, Freightliner, and International) to develop smarter trucks. As James Hebe of Freightliner Corporation put it in an address to the Tactical Wheeled Vehicle Conference in 2000, the truck of the future will involve the integration of components into a smart infrastructure of systems and a network of smart components.

It may be predicted that those OEMs who make tractors will need to interact more closely from the standpoint of system design with those who make trailers to the extent that tractors will not only pull trailers but also will have to communicate with them.

It is also anticipated that manufacturers will find value in having product lines that are highly modular and reconfigurable for specific missions and operations such as long-haul, regional, less-than-truckload, and local delivery. FMCSA will in turn have to move beyond a level of analysis that treats all trucks alike. Just as the industry thinks in terms of different types of commercial operations, so must FMCSA orient more to operations in its consideration of safety and security. If the industry is to become more efficient through a more informed focus on operations, FMCSA must also become more efficient in its safety and security efforts conducted in support of that industry.

FIGURE 8 Tractor 10-0994, International 9200, pulling triples on I-84 westbound at 207th Avenue overpass in Fairview, Oregon (Portland suburb). Photo by Wilt Warren.

More Tonnage and Bigger Trucks?

If trucks are going to be moving the majority of a significantly larger volume of freight, does that imply that in addition to more trucks, trucks will also tend to become bigger or longer? Such trucks will require an infrastructure that can accommodate them. If so, will roadway design, roadway construction, and roadway maintenance all have to be responsive to these changes? Can infrastructure needs anticipate the future needs of the vehicles that will be using them? Clearly there needs to be some integrated thinking on the part of the trucking industry and those who design, build, and maintain roads. Will triples commonplace in some parts of the western United States be a likely alternative in those highly populated eastern states where major increases in activity are forecast (Figure 8)? To what extent will the almost extinct rail system respond to the increased demand?

Smarter Trucks

Trucks will become smarter, with a much greater awareness of their real-time (and historical) operating status, and better able to communicate their awareness of these conditions to points beyond the truck. The ability of onboard diagnostic systems to capture anomalies and the real-time operating context in which they occur and alert those who must be prepared to provide just-in-time service will decrease down time and increase productivity. Such capabilities have been in place for quite some time in the military and defense and commercial aviation industries. It is predicted that onboard systems will not only be able to diagnose and record operating conditions but will also be able to reconfigure software-based systems dynamically to provide work-around solutions.

It is necessary to move quickly beyond associating CMVs simply with trucks and think in terms of the power unit, not only as the source of energy used to move the cargo but increasingly as the brains of the operation, which must maintain continuous awareness of the presence and condition of the cargo being transported, the physical integrity of the enclosure being used to contain the cargo (e.g., cargo tank, sea-going container), and the platform (e.g., trailer) on which the enclosure is being carried. It is unlikely that the future will be characterized by dumb trucks pulling smart containers (Figure 9).

Efforts to improve supply chain security through the use of various sensors and RFID technologies are already being seen and more can be expected. For these technologies to be widely adopted and implemented, FMCSA must take an active role, working closely with other components of government such as U.S. Customs and Border Protection to introduce initiatives like C-TPAT (Customs Trade Partnership Against Terrorism) and related initiatives that would offer shippers immediate turnaround

FIGURE 9 Smarter containers (content ID, status, and more) (presentation on toll truckways by Peter Samuel, annual fall symposium, urban transportation center, Chicago, October 29, 2004).

with no inspection on arrival in exchange for implementing more stringent requirements for ensuring effective monitoring against tampering from the point of origin with a verifiable record of events available to inspectors. The extent to which this can be achieved without government mandates remains the issue. The role of government in the case of container tracking throughout the global supply chain takes on international proportions when one considers the need for international standards.

Regarding FMCSA's enforcement responsibility, it will be necessary to rethink the extent to which the agency's responsibility remains limited to the safety and security of the cargo only after it has been loaded onto a commercial vehicle (truck) for transport. There will continue to be a need to define better the enforcement (and inspection) responsibilities associated with duties at intermodal transfer points whether they be ports or borders or points inside the continental United States and, as has been pointed out earlier, to recognize increasingly the extent to which the effectiveness of those procedures is dependent on limited and costly human resources.

Smarter Operators

Will such smart systems require smarter operators, that is, drivers? Not necessarily. To the extent that OEMs and third-party and after-market suppliers employ good human–machine interface design practices, a driver's need for understanding how the system works may actually be reduced. In contrast, OEMs will find that new skill sets are required for those who design the equipment. The dominance of mechanical engineers will have to give way to an increased mix of electrical and computer system engineers as well as human factors specialists. Although OEM design and manufacturing staff at the plant may need a new and different skill mix, OEMs will be required to focus not only on simplification of the operating environment for the driver but also on the job of the field maintenance technician. OEMs will find themselves rushing to develop expert system-based diagnostic systems that can effectively package and disperse the diagnostic and advanced troubleshooting skills of their experts to all parts of their market environment.

Currently technology is at a phase in which a number of new technologies are at the outset of their initial implementation, for example, fatigue monitoring, lane tracking, biometric driver identification and global driver log-in, vehicle tracking, off-route detection, geofencing, remote shutdown, stability augmentation systems, integrated communications [cellular, satellite, WiFi, dedicated short-range communication (DSRC), Bluetooth, RFID, etc.], untethered trailer tracking, onboard diagnostics, and alert notification. These technologies permit the truck to operate within a data-rich environment in which advanced telecommunications systems technologies permit the truck to acquire, process, and transmit information beyond its immediate physical environment.

Smarter Operations

Although derivatives and modifications and enhancements of these technologies can be expected, it is suspected that the real gains will be seen in those technologies and methodologies that provide the industry, including shippers, carriers, consignees, and others, with improved capabilities for operating and managing operations, that is, technologies and applications that will permit the industry to operate smarter and more efficiently. These information-oriented technologies will, it is predicted, make even greater use of the Internet and World Wide Web. Just as onboard computers, cell phones, GPS, and the like were considered science fiction as little as 30 years ago, the exact nature of these future technology applications lies, in many cases, beyond the range of the immediate imagination.

Summary

Although the truck of the future will be smarter, it will be forced to operate in an environment in which demand will likely exceed capacity, where efficiency will be sought through dynamic routing systems that will take into account real-time traffic and road conditions through communications capabilities that will keep operators and management in-touch, with electronics that will permit the industry to know the current location and status of its assets, with supply chain management applications that will permit cargo to be tracked from the time it leaves the plant to the time it reaches the end user. Cargo awareness will be pushed down to the pallet and item level. Such capabilities, now resident with large carriers and in that portion of the industry in which safety and security risks are high—hazmat, for example—will begin to become more routine throughout the industry.

Perhaps most important will be the need for collaboration and partnering between the regulatory and enforcement sides of government with industry in terms of shared responsibilities for safety and security. Common ground will have to be reached on the use of advanced technology for monitoring and surveillance. Privacy concerns at the company level will overtake concerns for individual privacy.

Enforcement will, in general, be forced to become more efficient, with fewer people needed to provide increased temporal (24 hours a day, 7 days a week, 365 days a year) and spatial (areawide) presence. Enforcement must provide convincing arguments to the industry that it can play a major risk-management and risk reduction role in industry operations.

Continuous tracking of commercial vehicles will become commonplace; tracking concerns will become secondary to the need for real-time information on the things being tracked (cargo, vehicles, etc.). C^3 system capabilities will be forced to become not just smarter but more intelligent. Information-gathering systems such as those that now characterize TSA and Homeland Security Information Sharing and Analysis Centers (ISACs) will have to develop capabilities to process archived and warehoused data to detect trends not apparent from response- and recovery-based alerting systems.

Commercial vehicle enforcement personnel will have to acquire new skill sets based increasingly on competency in advanced telecommunications system capabilities. These changes will be evident not only for the officer in the field but equally, if not more so, for the information techmology (IT) component of traditional law enforcement organizations. As the requirement for participation in an information-driven environment comes to bear on traditional law enforcement organizations and practice, the ability to link to other organizations and sources of data will increase. Law enforcement organizations that attempt to continue operating in isolation will not be effective. Cooperation and collaboration and not isolation will become the rule.

The effective reach and perceived presence of the individual commercial vehicle enforcement officer will extend well beyond the patrol vehicle. Traditional weigh stations will become a thing of the past as weigh-in-motion becomes more widely implemented and as vehicle-to-roadside, vehicle-to-vehicle, and vehicle-to-roadway communications become more commonplace. Traditional forms of pursuit and apprehension will give way to more electronic, cost-effective means. Adoption by the courts of more effective IT systems will support the increase in electronic ticketing by making it possible for penalties to come into contact with an individual's or company's pocketbook immediately.

The enforcement community needs to recognize that current concepts of e-ticketing, although they improve the administrative side of the ticketing process, may be no more effective than issuing a paper so long as enforcement remains constrained in its ability to observe the behaviors in question effectively and the courts remain inconsistent in their actions toward adjudication. Streamlining marginally effective enforcement concepts and practices is no guarantee of achieving the levels of compliance and control that are ultimately desired.

Perhaps the greatest change forecast for the future will be the increase in collaborative efforts between the motor carrier industry, the OEM and third-party suppliers of that industry, and enforcement. There will be an increasing recognition by enforcement that compliance can only in part be accomplished by punishing noncompliance. It is predicted that commercial vehicle enforcement will move more in the direction of community policing, that is, become more of a collaborative activity between enforcement and those whose behavior enforcement is trying to control. Only through the adoption of a more collaborative working approach can enforcement ever expect to operate with industry in a shared information environment in which enforcement is perceived as a full, risk-management partner of industry.

This collaboration will not be limited to that between government and the carrier industry but will extend to the OEM community. Safety and security must be built in. Enforcement cannot be expected to be the major source of commercial vehicle safety and security. Likewise, the DOT and state DOTs must begin and continue a more effective dialogue with the trucking and freight management industries in full recognition of the global and multimodal aspect of freight management. This recognition is predicted to result in the reorganization of traditional modal administrations and the closer cooperation of current administrations.

Implications and Recommendations for FMCSA Strategic R&T Program

A review of the goals and related research objectives in each of the three areas of the FMCSA R&T program fails to reveal any significant focus on CMV operations within the context of larger issues presented by future requirements associated with global supply chain management:

Program Area 1. Driver Safety Performance. Related FMCSA 2010 strategic objectives: (a) all commercial motor vehicle drivers are fully qualifed, safe, alert, and healthy and (b) the safety and performance of noncommercial drivers are improved for trucks.

Program Area 2. Commercial Vehicle Safety Performance. Related FMCSA 2010 stragetic objective: commercial motor vehicles have optimum safety performance.

Program Area 3. Carrier Compliance and Safety. Related FMSCA 2010 stragetic objective: facilitate improvement in the overall safety performance of the motor carrier industry through refined and enhanced safety management systems. (FMCSA 2005).

Within FMCSA there continues to be a microscopic focus on driver and vehicle performance and carrier compliance. For FMCSA to recognize the need to address cross-cutting initiatives, agency research will need to be sensitive to the broader context for CMV operations within a truly multimodal, global supply chain focus on freight management.

There is little evidence, for example, that the approach of FMCSA's Large Truck Crash Causation Study will cast any new light on the problem of truck-involved crashes. Clearly, the frequency of truck-involved crashes will continue to increase under conditions in which increases in the total number of vehicles (commercial and noncommercial alike) are expected to exceed increases in the number of lane miles available to accommodate the movement of those vehicles. Although industry trends toward the development of more crashworthy (noncommercial) vehicles will serve to decrease the likelihood of occupants' being killed in truck-involved crashes, as well as to produce a reduction in overall vehicle speeds due to congestion, there will continue to be significant numbers of persons killed, seriously injured, or both in truck-involved crashes.

It seems that FMCSA safety programs focus more on the dynamics of crashes than on the operational context in which these crashes occur. A strategic question should be, "How can we achieve a safer and more efficient means for the movement and delivery of goods than the present system, which requires heavy vehicles and smaller, less crashworthy vehicles to operate at high speeds under an increasingly congested, shared-use roadway environment?" And not only how it can be done more safely, but also more securely.

FMCSA needs to enter into a broader and more forward-looking dialogue with those focused on identifying more effective means for the movement of cargo and goods within what is likely to be a seriously constrained surface transportation environment. The products of a research program that focus almost exclusively on alert drivers, technologically advanced vehicles, and compliant carriers do not provide a sufficient guarantee of effective future operations.

Specific recommendations are as follows:

1. The safety, security, and efficiency requirements of enforcement should be embedded within a broader, more integrated concept of freight and global supply chain management. The current FMCS R&T program shows little awareness of the broader context in which future commercial vehicle operations will take place: 50% increase in tonnage by 2020, overwhelming modal dependence on trucking, lagging U.S. infrastructure and capacity, fluctuation in fuel prices, and congestion impacts on a just-in-time manufacturing environment operating in a multimodal, global supply chain. Enforcement and other means of internal system control need to become embedded components of an overall concept of system operations.

2. A portion of the FMCSA R&T program should be developed with a focus that is not constrained by current technology limitations and the need for immediate product adoption and implementation by the customer. One cannot effectively pursue the goals of a strategic R&T program when forced to operate within current technology limitations and system costs and the present customer's ability or willingness to adopt the products of the program. FMCSA's R&T programs need to get out in front of its near-term policy and implementation-driven focus (Figure 10). Development of new technology applications and implementation of them concurrently can't be expected. Trying to do so invites failure and loss of customer support. The FMCSA user is not the U.S. Department of Defense user. The adoption of new technology and its implementation are governed by a different process.

3. A significantly expanded focus on operations should be developed while the current focus on system safety and compliance continues. The current, modality-centered program focuses on safety and compliance at the operator and vehicle levels rather than on the major factors believed to affect safety and compliance of future operations. Safety and security need to be incorporated rather than being exclusively the domain of compliance.

4. A more realistic approach to the analysis of crash data should be developed with stronger logical and theoretical links to crash and injury reduction goals. Current safety improvement programs focused on the driver and the vehicle represent necessary, but not sufficient, means of addressing those operational factors that will significantly increase the crash involvement of commercial vehicles in the future. Given current forecasts for increasing congestion, it is quite likely that FMCSA could meet its 2008 strategic goal for a reduction in the rate of CMV-involved fatalities not as a result of its safety and enforce-

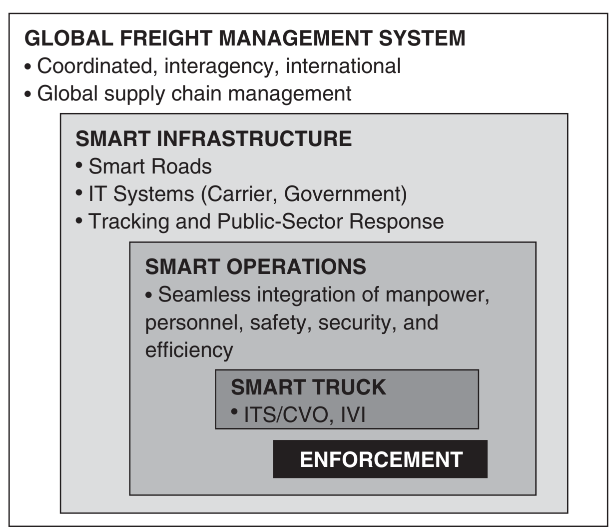

FIGURE 10 Future context for CMV enforcement (FMCSA 2005).

ment initiatives but from reductions in vehicle speeds associated with congestion. The continuation of current analysis methods and the thinking that underlies those methods cannot be expected to produce any useful insights in terms of major system improvements.

Analysis methods and approaches currently being used by FMCSA represent no value added to what are basically the same types of crash data analyses being conducted by NHTSA. FMCSA continues to pursue (crash) analysis methods, the thrusts of which (vehicle, roadway, driver) are holdovers from FMCSA's previous FHWA parentage. Research indicates that meaningful relationships are more likely found at the carrier level, where safety improvements are more likely to come from an increased focus on operations and process. This level of (operations-based) analysis should be the principal domain of FMCS.

Current analyses of crash data continue to focus on driver error. Some elements within a strategic R&T program should focus on the potential for autonomous vehicle control (in addition to lane keeping, intelligent cruise control, driver monitoring, and the like) under improved roadway conditions that provide effective physical or functional separation between vehicles with significantly different physical and operational characteristics. Although the products of current programs, such as the Intelligent Vehicle Initiative, suggest that technology is moving, albeit slowly, in the direction of more autonomous vehicle control with less associated possibility of crashes related to driver error, there needs to be an increased sense of urgency as to when these strategic goals are accomplished. The growing crash problem cannot continue to be fixed by using outdated methods.

5. Improved interagency collaboration should be developed that moves beyond current modality-centered programs. There is little evidence of strategic, interagency R&T planning within the DOT modal administrations, for example, collaborative efforts with FHWA on infrastructure design and operations, with NHTSA on increasing the survivability and occupant protection for those in CMV-involved crashes, with industry on future vehicle requirements associated with anticipated increases in freight tonnage, and with TSA and HSD on tracking and surveillance systems for other than hazmat requirements. Initial efforts toward interagency collaboration should come from the CVISN and the freight mobility sides of FMCSA and the freight management side of FHWA. Intermodal freight issues do not exist only at ports and border crossings. It is still not clear that there is a real and effective R&T program focus on intermodal operations. Saying that cargo is the Coast Guard's responsibility while the cargo is on the ship, that it is the responsibility of customs while it is moved from the ship to a common carrier (e.g., rail or truck), and that it becomes the responsibility of FMCSA once it is loaded on the truck from transport suggests that an effective seamless approach to freight management has yet to be developed.

6. Future concepts of operation within the trucking industry that are less dependent on human system costs and limitations should be developed. Trucking operations are extremely labor intensive as evidenced by the continued debate over driver hours of service (system operations constrained by human limitations on sustained operations associated with performance of a manual control task subject to the effects of fatigue and distraction; care and feeding costs of human components of the system, such as salary, benefits, and training costs; and the concept of one truck–one operator). The human component of the system (primarily the driver) can only be stretched so far before system safety becomes seriously compromised. Cheaper, less experienced drivers are not the solution; neither are efforts to minimize driver costs by resorting to longer, wider, and heavier combination vehicles.

7. Enforcement concepts of operation that provide increased spatial and temporal coverage with less dependence on human observers should be developed. The system will not be able to afford current personnel-intensive notions of CMV enforcement, which even under current staffing levels cannot support an areawide enforcement presence 24 h a day, 7 days a week (24/7). Successful automation of many administrative types of duties, such as report generation and data entry, will not be able to free up enough personnel sufficiently to meet increasing demands. Unmanned surveillance methods will be needed to monitor operations effectively, but such unmanned surveillance and monitoring may come with a real or perceived loss of personal (and company) freedom and privacy. New alternatives must be found to current time- and labor-intensive driver and vehicle inspection activities. R&T program goals need to focus on methods of ensuring compliance that are less dependent on the direct physical intervention of live, uniformed officers.

8. The FMCSA research focus on enforcement methods and strategies should be increased. Collaborative research efforts need to be developed with other agencies and organizations such as the Department of Justice and the International Association of Chiefs of Police (IACP). An approach to research in the enforcement area should be developed that goes beyond the narrowly defined role of compliance enforcement. What has been learned in the study of community policing and other programs in which enforcement and the public sector work in a more collaborative and cooperative mode should be incorporated. Collaboration with NHTSA's crash data R&D programs should be increased with the goal of establishing more effective means (e.g., use of geographic infor-

mation systems and GPS) for FMCSA enforcement personnel to utilize available crash data.

There is a clear need for increased collaboration with the courts. Legislation alone does not solve problems; neither does enforcement's best efforts to enforce existing laws. Without effective adjudication by the courts, there will be no compliance. The court system is as much a victim of its own labor-intensive practices as law enforcement. It is essential that the courts and law enforcement begin to work out of a common recognition of these problems to develop judicial practices that are capable of achieving their intended effect. The courts and law enforcement are, in most cases, trying to achieve the same thing: improved social control. There needs to be a joint recognition that law enforcement and the courts have a social responsibility to do more than just punish the bad guys.

9. Technology should be used to increase the effective spatial and temporal coverage of uniformed officers. There needs to be a major R&T focus on the development of enforcement methods and strategies that are compatible with technological developments occurring within the industry, which has enforcement responsibility. There needs to be more R&T focus on what it means for motor carrier enforcement to be able to operate in what will be an increasingly wireless, telematics-driven carrier operating environment. The future will dictate that enforcement be able to monitor commercial driver, vehicle, and load status by electronic means without having to stop the vehicle for a physical inspection. It is predicted that despite current industry resistance to the adoption of onboard electronic data recorders and electronic log books, these capabilities will become routine, either because of carrier acceptance as to their management effectiveness or because of government mandates ordering their adoption.

10. Enforcement models and strategies should be developed that emphasize collaboration and government–industry cooperation. The current compliance-based model of CMV enforcement focuses on catching the bad guy rather than on collaborative and proactive steps to ensure safety. The motivation comes from putting drivers and vehicles out of service, collecting fines and penalties, and maintaining records of weight. The current enforcement philosophy makes it difficult for an officer to imagine what it would be like to experience a day when, despite intense enforcement effort, not a single driver or vehicle could be placed out of service or found to be overweight. Yet that is the goal of compliance.

Enforcement needs to become part of the productivity and risk management equation for the industry. Only when the industry perceives a true benefit from collaboration with enforcement will there be the level of data sharing required to achieve current security goals.

11. What is likely to continue in terms of the states' technical and financial difficulty in effectively implementing new technologies and system concepts should be recognized. From a product development and implementation standpoint, more effective models should be developed for the concurrent (versus staggered) adoption and implementation of new technologies and system concepts. This change will become increasingly important for information-intensive system concepts that are dependent upon the reliable acquisition and sharing of information between states. There clearly needs to be a better approach to achieving more consistent, across-the-board adoption of new technologies and system capabilities at the state level than the current approach of unfunded, federal mandates. Just as the carrier industry must perceive the benefits associated with implementation of a new technology or system capability, so must the states. An effective R&T program oriented to the trucking industry needs to consider that technology development and implementation in the commercial sector is a very different—that is, voluntary—process than technology development and implementation in the top-down military and defense sector.

References

AASHTO. 2003. *Recommendations for Bridge and Tunnel Security*. Blue Ribbon Panel on Bridge and Tunnel Security Transportation Security Task Force, September 2003. http://www.fhwa.dot.gov/bridge/security/ brp .pdf. Accessed February 2005.

California Engineer. Spring–summer 2003. Transportation Technology and the Future of Transportation: Platforms of the Intelligent Vehicle Initiative, Vol. 81, Issue 3, pp. 15–19. http://caleng.berkeley.edu/archive/sprsum2003/ The%20Future%20of%20Transportation.pdf. Accessed February 2005.

Cambridge Systematics. 2005. *Driver, Vehicle, and Roadside Strategies for 2010*. Federal Motor Carrier Safety Administration. http://www.camsys.com/casee02.htm. Accessed February 2005.

FHWA. 2004. *Freight Facts and Figures 2004*. Freight Management and Operations Office, U.S. Department of Transportation. http://www.ops.fhwa.dot.gov/freight/ freight_analysis/nat_freight_stats/docs/04factsfigures/in dex.htm. Accessed February 2005.

FMCSA. 2005. *Executive Summary*, *Motor Carrier Research and Technology Program Overview*. U.S. Department of Transportation. http://www.fmcsa.dot.gov/espa% C3%B1ol/saftresearch_sp_main.htm. Accessed February 2005.

FMCSA Website. U.S. Department of Transportation. http://www.fmcsa.dot.gov. Accessed February 2005.

Geo-Decisions, Inc. 2005. *IRRIS Project Description*. http://www.geodecisions.com/projdescrip.asp?Project ID=181. Accessed February 2005.

Ham, D. B., and S. Lockwood. 2002. *National Needs Assessment for Ensuring Transportation Infrastructure Security*. Parsons Brinckerhoff, Inc., Herndon, Va., October. http://security.transportation.org/doc/NatlNeedsAssess.pdf. Accessed February 2005.

Hoemann, W. 2003. Remarks, United Motor Coach Association Board of Directors Meeting, June 20. http://www.fmcsa.dot.gov/contactus/press/speeches/umabod.asp. Accessed February 2005.

Intelligent Vehicle Initiative. 2005. *Commercial Vehicles and Interstate Buses* (online list of published reports). http://www.its.dot.gov/ivi/searchresults.asp?VP_C=True&DocTypeR=True. Accessed February 2005.

Knipling, R. R., J. S. Hickman, and G. Bergoffen. 2003 *CTBSSP Synthesis of Safety Practice 1: Effective Commercial Truck and Bus Safety Management Techniques*. Commercial Truck and Bus Safety Synthesis Program, TRB, National Research Council, Washington, D.C. http://trb.org/publications/ctbssp/ctbssp_syn_1.pdf. Accessed February 2005.

National Intelligence Council. 2004. The Contradictions of Globalization. In *Mapping the Global Future: Report of the National Intelligence Council's 2020 Project*.

The Road Information Program (TRIP). 2004. *America's Rolling Warehouses: The Role of Increasing Trucking on Economic Development, Congestion, and Traffic Safety*. Washington, D.C. February. http://www.tripnet.org/TruckingReport020904.pdf. Accessed February 2005.

Salazar, S. 2004. Expanded Commercial Vehicles Information Systems and Networks (CVISN). FMCSA, Presented at Commercial Vehicle Freight and Mobility Forum, September 2004. http://www.itsa.org/resources.nsf/Files/Sandra%20Salazar%20%20Preliminary%20Framework%20for%20Expanded%20CVISN/$file/ExpCVISNVotingPkg%202004-08-12%20R2.pps. Accessed February 2005.

Sandberg, A. M. 2003. The Role of IVI in Highway Safety. Presented at National Intelligent Vehicle Initiative Meeting, Washington, D.C. June. [Slides of Ms. Sandberg's presentation available online at http://www .fmcsa.dot.gov/contactus/press/speeches/role.asp. Accessed February 2005.]

Science Applications International Corporation. 2003. *Hazardous Material Transportation Safety and Security Field Operational Test Final Detailed Test Plans*. ITS Joint Program Office, FMCSA, U.S. Department of Transportation. September 16. http://www.itsdocs.fhwa.dot.gov/jpodocs/repts_te/13899.html. Accessed February 2005.

Society of Motor Manufacturers and Traders, Ltd. 2004. *Foresight Vehicle Technology Roadmap: Technology and Research Directions for Future Road Vehicles*. Forbes House, London, October. http://www.foresightvehicle.org.uk/info_/FV/TRMV2.pdf. Accessed February 2005.

U.S. Department of Transportation. 2003. *Safer, Simpler, Smarter Transportation Solutions: Strategic Plan 2003–2008*. September. http://www.dot.gov/stratplan2008/strategic_plan.htm. Accessed February 2005.

Walton, C. M. 2004. Freight Transportation Policy. Presented to North Carolina State University Transportation Founders Fund, Raleigh, March 16. http://www.itre.ncsu.edu/ITREmain/TFF/downloads/TFF-Walton-FreightPres.pdf. Accessed February 2005.

Driver Health and Wellness

Michael Belzer, *Wayne State University, Provocateur*
Edward Hitchcock, *National Institute of Occupational Safety and Health*
LaMont Byrd, *International Brotherhood of Teamsters*
Donald Osterberg, *Schneider National, Inc.*
Mark Rosekind, *Alertness Solutions*
E. Lee Husting, *National Institute of Occupational Safety and Health, Moderator*

The overall goal of National Institute of Occupational Safety and Health (NIOSH) research is to improve and preserve the health and wellness of individuals employed in the commercial truck and bus industry. Important aspects include safety, injury prevention, health, and wellness.

The immediate research goal should be to obtain reliable baseline data and to understand factors that influence risk in the next 5 to 10 years. Then, identified and implemented 10-year interventions should be evaluated, and those that are successful should be widely disseminated.

In contrast to crash data, data on the health and wellness of truck and bus drivers, and indeed even the general public, are largely lacking. Research should produce published scientific evidence that addresses whether fitness, exercise, and healthy lifestyles affect long-term truck driver health, mortality, fatigue, and driving performance leading to tested interventions.

Role of NIOSH

NIOSH conducts research and makes recommendations for the prevention of work-related injury and illness. In 2004 NIOSH established its Occupational Motor Vehicle Safety and Health Program as a new National Occupation Research Agenda activity to address safety and health concerns for all workers who operate a vehicle as a function of their jobs. NIOSH has established a steering committee with scientists from major divisions, funding, and a mandate to create a center and encourage research. The initiative is led by Stephanie Pratt.

The Concept for an Extramural Research Initiative to address occupational injury and illness among truck drivers has been prepared within NIOSH. It is linked to the Occupational Motor Vehicle Safety and Health Program. Partnerships with other agencies are being actively sought.

This initiative is expected to result in a NIOSH request for applications (RFA) for funded research in 2006 or 2007. The RFA will focus on the effects on drivers of operating a large truck. Specific interest is placed on the revised hours-of-service rule, musculoskeletal disorders, chronic disease, and acute injuries.

History of NIOSH Research

Past Research

In the past, NIOSH used epidemiologic methods to conduct a study of the effectiveness of collision avoidance technology in preventing crash-related injuries. The results were inconclusive; however, a number of partnerships were established and lessons were learned regarding research in transportation. Other transportation-related studies have examined the following topics:

- The relationship between truck driver injury and illness and vehicle condition and work practices. This relationship would confirm the possible usefulness of this line of research (Husting and Biddle 2003a).

- The economic consequences of crashes on the public, the drivers, and the industry (Husting and Biddle 2003b).
- A driver training safety program that included skid pad practice, simulator training, classroom instruction, fitness to drive, and roadway conditions (Husting and Proudfoot 2002).

Current Research

Current NIOSH research interests include

- A West Virginia driver training program for firefighters, with results that may have implications for training other drivers;
- A book chapter on the state of trucker health and safety in the age of information;
- A study of cause-specific rates of mortality from 1985 to the present among independent owner–operators; and
- A study based on interviews with 1,000 women truck drivers. Women are increasingly being recruited to the industry, but little is known about the health and wellness issues that might affect women differently from men. For example, preliminary results show that 85% of women drivers are obese or overweight, and 13% have been threatened with violence.

Research Needs

- The relationship between driver health and wellness and driver safety, as well as public safety: the research should lead to effective interventions as well as the ability to develop and maintain a knowledge base on truck and bus driver health and wellness.
- Scientifically evaluated wellness interventions with the results made available quickly.
- Nonfatal injuries and especially musculoskeletal disorders (a rapidly evolving field of investigation), such as those of the knees, hips, ankles, and shoulders; slips, trips, and falls as well as events relating to vehicle ingress and egress, which are probably a substantial cause of driver injury; and health care, insurance, workers' compensation costs, and lost work time.
- Based on current efforts, such as the results of the cohort mortality study of Owner-Operator Independent Driver Association (OOIDA) drivers, which could inform similar studies of other truck and bus workers; results from the mortality study may indicate topics for further attention, such as case-control studies of specific problems.
- A variety of methods including epidemiological, clinical, and experimental studies, which should draw from all relevant disciplines including health, medicine, ergonomics, safety, human factors, behavioral science, economics, and management.
- Focus on Research to Practice (R2P) with emphasis on implementation and practice: collaborative research practices will be imperative for accomplishing this goal.

Commentary

Michael Belzer

Key Points

- Safety costs are large but health costs are larger.
- Health costs are difficult to quantify because the consequences are long term and cumulative. There is a long delay between exposure and illness.
- Drivers are exposed to a variety of conditions that are conducive to poor health. Long hours and an irregular sleep cycle are occupational hazards.
- Sleep deprivation leads to chronic illness. It is associated with endocrine disruption, weight gain, sleep apnea, diabetes, and heart disease.

Future Scenario

- Trucking is market driven and governed by a business model.
- Carriers self-manage by using benchmarking techniques to identify and establish best practices.
- Safety and health are key benchmarking issues.
- Regulation is data driven.
- Truck and bus driving are decent jobs.
- Research is collaborative with emphasis on implementation.

Consequences of Failure to Change

- If the job is not made more appealing, the chronic driver shortage will continue.
- Replacing American drivers with Mexican drivers will merely shift the problem.
- If the market does not support a solution, change is unlikely.

Research Needs

- An understanding of the market forces that drive the truck and bus industries.

- The long-term costs associated with the health of drivers.
- Change from a prescriptive regulatory environment to one driven by benchmarking and the adoption of best practices.

Panel Discussion

Edward Hitchcock, LaMont Byrd, Donald Osterberg, and Mark Rosekind

Key Points

Edward Hitchcock

- More than half of all occupational injuries occur in trucking.
- Compensation by miles driven is an incentive to speeding and hours-of-service violations.
- There is a twofold increase in heart attacks, more prevalent severe back injuries, and increased risk of lower back injury in workers on the job 60 hours or more per week.
- Overtime work is associated with health decline, weight gain, and other health deficits.
- Injuries increase after 9 hours on the job, and the risk is higher in night workers.

LaMont Byrd

- Driving skills in the aging worker force will be further compounded by the need to interface with new technologies.
- The workforce will be increasingly diverse and include more women, Hispanics, Asians, and African Americans.

Research Needs

Edward Hitchcock

- Focus on individual drivers to identify risk factors for specific industry segments, such as those who work long hours.
- "Hard science" (experimental) research rather than epidemiological studies.

LaMont Byrd

- The interrelationship between driver health and safety that considers smoking, exercise, nutrition, and other lifestyle factors.
- Effective programs for improving driver health.
- Conditions concerning port drivers, including security technology (gamma rays), exposure to diesel fumes when sitting in line waiting to load and unload, and radiation associated with hauling spent nuclear rods and other nuclear waste materials.

Mark Rosekind

- Measurement of the benefits associated with increasing health and safety.
- New developments in technology, medications, and other innovations that may affect driver health and safety.

DRIVER HEALTH AND WELLNESS: PRESENTATION

Health and Wellness
Future Truck and Bus Safety Research Opportunities

E. Lee Husting

In 2005 the health and wellness of truck and bus workers and drivers are not well understood, in contrast to the well-known public health problem of fatalities involving commercial vehicles. In the next 20 years research will produce published scientific evidence that addresses possible interactions among fitness, exercise, and healthy lifestyle and long-term driver health, mortality, fatigue, and driving performance. Such research should generate testable interventions. Research partnerships between federal agencies, academic institutions, and industry stakeholders should address these complex relationships and develop and maintain a knowledge base on truck and bus driver health and wellness. Wellness interventions should be scientifically evaluated and the results made available quickly.

In the next 5 years the immediate research goal is to obtain reliable baseline data and understand factors that influence risk. On the basis of current efforts, this goal seems attainable. The overall goal of relevant occupational health and safety research will be to improve and preserve the total health and wellness of employees in the commercial truck and bus industry. Safety and injury prevention and health and wellness all are important aspects of this program. A useful overview is provided in a publication by the TRB Truck and Bus Safety Committee (Krueger et al. 2005).

There are inherent difficulties in doing intervention evaluation research. It is difficult to demonstrate scientifically the absence of an effect, such as a reduction in illness or injury, and even more difficult to prove that such an effect is causally linked to an intervention. For example, a multifaceted, multiyear intervention program including exercise, medical examinations, training, and incentives was accompanied by a dramatic reduction in back injuries among petroleum drill-rig employees (Maniscalco et al. 1999). When the program was temporarily halted, injuries returned, and when the program resumed, injuries dropped in frequency. However, it was not possible to know which component of the intervention may have caused the decrease in back injuries. Similar difficulties may be expected in testing intervention programs for drivers.

Unique aspects of commercial transportation make it different from other sectors. One major difference is that the workplace is the vehicle. Although this review focuses mainly on truck drivers, it is recognized that commercial bus drivers are an important and distinct occupational group. Some comparisons have been presented in a TRB Synthesis (Grenzeback et al. 2005). A major difference distinguishing bus drivers is that they are transporting passengers, which affects their work schedules.

Current Activities

Several agencies and groups are engaged in relevant research, including the FMCSA and the NIOSH. NIOSH provides leadership in conducting research into work-related injury and illness. In 2004 NIOSH established an Occupational Motor Vehicle Safety and Health Program as a new NORA activity to address safety and health concerns for all workers who operate a vehicle as part of their job. To accomplish this effort, NIOSH established a steering committee with scientists from major disciplines, with funding and a mandate to create a center and encourage research, which has evolved into a transportation initiative.

A Concept for an Extramural Research Initiative to address occupational injury and illness among truck drivers was prepared within NIOSH in 2005. It is linked to the NIOSH Occupational Motor Vehicle Safety and Health Program. Partnerships with other agencies will be actively sought. This will result in a NIOSH request for applications (RFA) for funded research in 2006. The RFA will focus on the effects on drivers of operating a large truck, in particular the revised hours of service, musculoskeletal disorders, chronic disease, and acute injuries

NIOSH is emphasizing approaches that are immediately relevant to health, wellness, and safety research. Research to Practice, or R2P, refers to the translation of research results into practice and the environment of the practitioner. Considerable attention is now given to measuring the impact on reducing morbidity and mortality by scientific methods of intervention and evaluation. For example, NIOSH cosponsored the Conference on Steps to a Healthier U.S. Workforce in October 2004.

A number of basic studies sponsored by NIOSH are under way. A study of cause-specific rates of mortality from 1985 to the present is being conducted with data from the OOIDA. This study should provide mortality rates pinpointing causes of death that are relatively high in truckers and generate hypotheses for more focused epidemiological studies. Separately, a study of the influence of work organization on fatigue in truck drivers is being conducted by university researchers and government scientists. Several other NIOSH-sponsored projects focus on other aspects of transportation, such as ambulance crashes and risk factors for crashes affecting public employees.

Trends

Obvious technical, social, and demographic changes will affect the health and safety of commercial drivers. One change is the rapidly proliferating information technology providing feedback on vehicle status, traffic conditions, and the immediate driving environment. The impact of information technology on driver well-being is explored in a review of trucker health and safety in the age of information. This review explores the application of a public health approach to truck driver health and safety in the face of proliferating information technologies (Husting and Biddle 2005).

Other changes may include drivers' demographics and increased social and cultural diversity including language and gender differences. The size of the white male population aged 35 to 54 is declining. Currently this group includes more than half of all truck drivers. The share of Hispanic drivers is increasing, although the growth of the overall labor force is declining. About 54,000 new truck drivers per year will be needed over the next decade. There is currently a shortage of about 20,000 truck drivers, which is projected to increase to 111,000 by 2014. Wage competitiveness has fallen sharply, and to attract workers, wages must return at least to their earlier relative position. These factors affect not only the type of drivers entering the workforce but also current drivers and their lifestyles (Global Insight 2005).

Some research is focusing on women drivers, a topic that has only recently been explored. Preliminary results suggest that a substantial proportion of women drivers have experienced violence or threats of violence or are affected by fear of violence (Debra G. Anderson, personal communication, 2005). Many truck drivers do not have ready access to adequate health care. In a recent cross-sectional survey almost half of long-haul truckers reported not having a regular health care provider (Solomon et al. 2004). The authors noted, "Long distance drivers are at risk for poor health outcomes and experience difficulty accessing healthcare services." It is not uncommon for truckers in effect to be living on the road with their trucks as the primary domicile. These issues are ripe for research.

A Concept for an Extramural Research Initiative to Address Occupational Injury and Illness Among Truck Drivers was prepared within NIOSH in 2005. It is linked to the NIOSH Occupational Motor Vehicle Safety and Health Program. Partnerships with other agencies will be actively sought. This effort will result in a NIOSH request for applications for funded research in 2006. The RFA will focus on the effects on drivers of operating a large truck, in particular the revised hours of service, musculoskeletal disorders, chronic diseases, and acute injuries.

In a recent editorial in the *New England Journal of Medicine*, the effects of sleep deprivation on medical interns were compared with the potential effects on truckers in the context of hours of service (Wylie 2005). Wylie notes that sleep debt and circadian rhythms, associated with irregularity of sleep; food; recreation; and exercise are likely to affect drivers. Another study reported that extended work shifts increased the risk of near misses and falling asleep and doubled the risk of a motor vehicle crash (Barger et al. 2005).

Both sleepiness and fatigue and distraction and inattention have been shown to increase the likelihood that a commercial vehicle crash will be fatal (Bunn et al. 2005). This epidemiological study may be the first scientific evidence linking police crash report indication of state of the driver to the likelihood of a fatal crash outcome. Age greater than 51 years and nonuse of safety belts also were associated with increased fatal crashes. The authors suggest that driver education regarding fatigue, rest breaks, or policy changes might mitigate this problem. These changes could be translated into testable intervention hypotheses. Another study concluded that fatigue management education for drivers may be an effective countermeasure (Gander et al. 2005). At a public policy forum held in March 2005 by the National Sleep Foundation, sleep deprivation was recognized as a public safety issue (Lamberg 2005).

Future studies of driver–vehicle interactions are needed. The first available crash data–based evidence on collision warning systems (CWS) suggests that CWS-equipped trucks had significantly fewer crashes involving other moving vehicles and significantly fewer multiple-vehicle crashes compared with trucks lacking these systems (Chen et al. 2004).

An important focus for future research should include nonfatal injuries, particularly musculoskeletal disorders (knees, hips, ankle, shoulders, etc.). Trips and falls related to vehicle ingress and egress are probably an important cause of driver injury, need for health care, lost work time, insurance, and worker compensation costs. Research into work-related musculoskeletal disorders is a rapidly evolving field in which the interaction of various risk factors is being investigated. In a recent study of Oregon truck drivers, claims citing sprains were found to be the most frequently cited injury (McCall and Horwitz 2005).

The medical requirements for obtaining a commercial driver's license are intended to ensure a reasonable level of baseline health and fitness to drive. However, preliminary evidence suggests that commercial drivers may be at increased risk of early mortality and various chronic illnesses related to lifestyle. Lack of exercise and unbalanced diets may lead to obesity, cardiovascular disease, and diabetes. These diseases may in turn relate to musculoskeletal disease and impaired driving ability.

Evidence from studies of other professions suggests that fatigue impairs performance and should be studied in drivers. The role of fatigue in traffic crashes and driver performance has been explored. For trucking, one aspect of this issue is that the driving environment does not appear to offer easy access to suitable rest stops with exercise facilities. Following this line of research, anecdotal evidence also suggests that there may be a need for research into some potentially controversial topics. For example, reports from international studies suggest that commercial drivers are likely to encounter sex workers and may become victims and perhaps vectors of AIDS and other diseases. There is some anecdotal evidence that truck rest stops may be focal contacts for sex workers in the United States as well and also may be noisy or dangerous. Violence and terrorism are plausible threats to commercial drivers. All of these conditions plus concerns about pay are expected to contribute to a continued shortage of drivers.

Antiterrorism concerns are also affecting truckers. As of May 2005, truckers who haul hazardous waste face immigration and criminal background checks before renewing their special commercial licenses. This review affects about two-thirds of U.S. drivers and is expected to cost taxpayers about $72 million in the first 5 years (Hall 2005).

The effects of prescription and nonprescription drugs on driver health are largely unknown. For example, drugs are used by truckers to combat fatigue or drowsiness. Programs such as "Getting in Gear" should be evaluated in terms of the long-term health effects. Additionally, new and innovative methods of providing exercise and encouraging fitness are needed.

A recent study (Robinson and Burnett 2005) reported an increase in lung cancer mortality in long-haul truck drivers younger than age 55 at death. These results suggest the need for a longitudinal epidemiological study to confirm and elucidate these findings.

The current controversy regarding hours-of-service regulations for trucking and the need for additional relevant health data has stimulated communication between various agencies and researchers. These communications should be maintained and formalized into partnerships. NIOSH, through the Office of Extramural Programs, currently sponsors research into immediately relevant areas including traumatic injury, violence, organization of work, and musculoskeletal disorders. These studies may produce results that suggest avenues of intervention research into driver health-related factors.

Future Needs

The necessary research for health and wellness will be costly and will need to be conducted over a number of years. It will require collaboration and partnerships between industry leaders, driver organizations, government agencies, university researchers, and health and medical professionals. Since the ultimate goal is the health and wellness of individual drivers, each driver must be encouraged to assume responsibility for minimizing risk factors and embracing a healthy lifestyle. This suggests that additional research into how to encourage fitness and exercise and how to measure the impact is needed.

Future research should build on current efforts; for example, the results of the cohort mortality study of OOIDA drivers could inform similar studies of other truck and bus workers. Results from the mortality study may indicate topics for further attention, for example, case control studies of specific problems.

Future research should utilize a variety of methods including epidemiology, clinical studies, and experimental studies and should draw from all relevant disciplines including health, medicine, ergonomics, safety, human factors, behavioral science, economics, and management.

Truckers may experience frequent and extended periods of eye closure while driving when fatigued. Devices such as Perclos are now available to measure the frequency and duration of these effects. The effects of fatigue may be cumulative and may reflect a variety of causal factors. It will require the latest methods of study to determine the effects of an additional hour of driving on trucker health. Future research should address real-time monitoring of the physiological state of drivers and methods to provide appropriate feedback to the driver to facilitate any needed corrective action, such as rest stops.

Although further studies are needed, these will require time, resources, and ingenuity to complete. In the meantime, it seems clear that the overall lifestyle required by extended driving hours probably has a negative impact on driver health, wellness, and performance. Individual improvements in diet, exercise, sleep, and health care should be encouraged and facilitated in the interim.

References

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

Bunn, T. L., S. Slavova, T. W. Struttman, and S. R. Browning. 2005. Sleepiness/Fatigue and Distraction/Inattention as Factors for Fatal Versus Nonfatal Commercial Motor Vehicle Driver Injuries. *Accident Analysis & Prevention*, May.

Chen, G. X., E. L. Jenkins, and E. L. Husting. 2004. A Comparison of Crash Patterns in Heavy Trucks With and Without Collision Warning System Technology. SAE Technical Paper. Presented at SAE Commercial Vehicle Engineering Congress and Exhibition, October, Rosemont, Ill.

Gander, P. H., N. S. Marshall, W. Bolger, and I. Giring. 2005. An Evaluation of Driver Training as a Fatigue Countermeasure. *Transportation Research Forum, Traffic Psychology Behavior*, Vol. 8, No. 1, pp. 47–58.

Global Insight. 2005. *The U.S. Truck Driver Shortage: Analysis and Forecasts*. American Trucking Associations.

Grenzeback, L. R., S. Lin, and J. Meunier. 2005. *CTBSSP Synthesis of Safety Practice 6: Operational Differences and Similarities Among the Motorcoach, School Bus, and Trucking Industries*. TRB, National Research Council, Washington, D.C.

Hall, M. 2005. *USA Today*, April 19. Truck Drivers Bristle at Anti-Terror Rules.

Husting, E. L., and E. A. Biddle. 2003a. Truck Driver Occupational Injury and Safety Interview Data. In *Safety in Numbers: Working Together from Research into Practice*, National Injury Prevention and Control Center, Centers for Disease Control and Prevention. Atlanta, Ga., May 27-29.

Husting, E. L., and E. A. Biddle. 2003b. The Cost to Society of Fatal Occupational Injury to Truck Drivers. In *Proceedings of the National Occupational Injury Research Symposium*, National Institute for Occupational Safety and Health, Pittsburgh, Pa., October 29, p. 87.

Husting, E. L. and E. A. Biddle. 2005. Motor Carrier Safety in the Age of Information. In *Trucking in the Age of Information*, Ashgate Publishing, London.

Husting, E. L., and S. Proudfoot. 2002. Evaluation of Outcome of an Emergency Vehicle Driver Training Program. *Project to Evaluate the Effects of an Emergency Vehicle Operator Course on Driver Performance*. Submitted in collaboration with the Driver Training and Safety Institute, Inc., to the Division of Safety Research, National Institute of Occupational Safety and Health, Morgantown, W. Va., October.

Krueger, G., M. H. Belzer, A. Alvarez, R. R. Knipling, E. L. Husting, R. M. Brewster, and R. H. Siebert. 2005. *Transportation Research Circular: Health and Wellness of Commercial Drivers*. Truck and Bus Safety Committee, TRB, National Research Council, Washington, D.C., in press.

Lamberg, L. 2005. Sleep Deprivation Recognized as a Public Safety Issue. *Psychiatric News*, Vol. 40, No. 12, p. 22, June 17.

Maniscalco, P., R. Lane, M. Welke, J. H. Mitchell, and E. L. Husting. 1999. Decreased Back Injuries Associated with Wellness. *Journal of Occupational and Environmental Medicine,* Vol. 41, No. 9, pp. 813–820.

McCall, B. P., and I. B. Horwitz. 2005. Occupational Vehicular Accident Claims: A Worker's Compensation Analysis of Oregon Truck Drivers 1990–1997. *Accident Analysis & Prevention*, in press.

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

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

Wylie, C. D. 2005. Sleep, Science, and Policy Change. *New England Journal of Medicine*, Vol. 352, No. 2, pp. 156–157.

Workforce Composition, Skills, and Training

Brenda Lantz, *North Dakota State University*
Rebecca Brewster, *American Transportation Research Institute*
Richard Clemente, *Professional Truck Driver Institute, Inc.*
Jerry Wachtel, *Veridian Group, Inc.*
Konstantin Sizov, *Drive Square, LLC*
Donald L. Fisher, *University of Massachusetts*
Ronald Mourant, *Northeastern University*
Christopher M. Crean, *Peter Pan Bus Lines*
Kevin Lewis, *American Association of Motor Vehicle Administrators, Moderator*

Figure 1 demonstrates the role of crashes in the overall number of deaths due to unintentional injury. It shows clearly why research to reduce crashes, injuries, and fatalities should be paramount. Achieving the goal is made more difficult by introducing more technologies into the driving environment. Some of the technologies, such as satellite navigation, lane departure warning systems, and infrared night vision, are intended to improve safety; however, there are also many entertainment technologies, such as MP3s and DVD players, bright LCD screens, digital cameras, game controllers, and wireless communications devices and fax machines. Distracting billboards and signage add to the problem.

The standard suggested by the Society for Automotive Engineers (SAE) is that any navigation function accessible by the driver while a vehicle is in motion should have a static total task time of less than 15 s. However, a vehicle travels more than ¼ mi at 65 mph in 15 s. An 80,000-lb vehicle requires 525 ft to stop from 65 mph on dry, level ground.

The SAE standard is based on static task time. The time to perform this task in the real world will likely take much longer. The study that produced the standard focused only on navigation functions and not on other in-vehicle distracters, and the test participants were trained and given five practice sessions before they were timed. The SAE standard appears to be deficient for preventing crashes. "Truck/bus driving is hours of boredom interrupted by moments of terror" (SAE 2000). Professional drivers are highly trained and experienced for the vast majority of situations that are likely to occur on the road. It is the rare, unforeseen event, often caused by the passenger vehicle, for which they may be less well prepared. On-the-job training, practice in actual vehicles on test tracks, classroom training, videos, or films do not adequately prepare drivers for these moments of terror.

According to Wachtel et al., one solution lies in the use of simulators. These devices are used in other professions—for example, by airline pilots, nuclear power plant operators, and ship captains—to prevent catastrophic incidents and should be seriously considered in the truck and bus industries. Making a mistake and crashing is not a failure in a simulator; it is part of the learning process.

Most of the objections to the use of simulators are understandable, but they are overstated or nonexistent. Small, part task simulators can be located anywhere and used anytime for practice to drive a new route, refresh a skill, or prepare for a challenge, such as black ice in the Sierras, a dust storm in Arizona, or a blizzard in Wyoming.

Future Scenario

Jerry Wachtel

- Fully national CDL with training and retraining requirements.
- Ability by commercial drivers to gain continuing education credits for time spent in kiosk-based simulators.

	Age Groups										
Rank	<1	1-4	5-9	10-14	15-24	25-34	35-44	45-54	55-64	65+	Total
1	Unintentional Suffocation 614	Unintentional MV Traffic 558	Unintentional MV Traffic 660	Unintentional MV Traffic 884	Unintentional MV Traffic 10,513	Unintentional MV Traffic 6,759	Unintentional MV Traffic 6,891	Unintentional MV Traffic 5,422	Unintentional MV Traffic 3,328	Unintentional Fall 11,623	Unintentional MV Traffic 42,443
2	Unintentional MV Traffic 139	Unintentional Drowning 458	Unintentional Drowning 168	Unintentional Drowning 165	Homicide Firearm 4,200	Homicide Firearm 3,308	Unintentional Poisoning 5,036	Unintentional Poisoning 3,547	Suicide Firearm 2,083	Unintentional MV Traffic 7,256	Suicide Firearm 16,869
3	Homicide Other Spec., Class. 117	Unintentional Fire/burn 230	Unintentional Fire/burn 164	Suicide Suffocation 163	Suicide Firearm 2,130	Suicide Firearm 2,564	Suicide Firearm 3,030	Suicide Firearm 3,023	Unintentional Fall 1,004	Unintentional Unspecified 5,806	Unintentional Fall 15,019
4	Homicide Unspecified 107	Homicide Unspecified 146	Homicide Firearm 59	Homicide Firearm 121	Unintentional Poisoning 1,362	Unintentional Poisoning 2,507	Homicide Firearm 1,978	Suicide Poisoning 1,439	Unintentional Poisoning 798	Suicide Firearm 3,943	Unintentional Poisoning 14,078
5	Unintentional Drowning 68	Unintentional Suffocation 138	Unintentional Other Land Transport 48	Suicide Firearm 90	Suicide Suffocation 1,235	Suicide Suffocation 1,373	Suicide Poisoning 1,541	Unintentional Fall 1,024	Suicide Poisoning 578	Unintentional Suffocation 3,204	Homicide Firearm 11,348
6	Unintentional Fire/burn 50	Unintentional Pedestrian, Other 81	Unintentional Suffocation 44	Unintentional Fire/burn 88	Unintentional Drowning 596	Homicide Transportation-Related 842	Suicide Suffocation 1,534	Suicide Suffocation 952	Unintentional Fire/burn 395	Adverse Effects 1,995	Unintentional Unspecified 7,218
7	Undetermined Suffocation 47	Homicide Other Spec., Class. 80	Unintentional Fall 33	Unintentional Other Land Transport 83	Homicide Cut/pierce 481	Suicide Poisoning 753	Undetermined Poisoning 1,121	Homicide Firearm 934	Suicide Suffocation 392	Unintentional Fire/burn 1,147	Suicide Suffocation 6,198
8	Homicide Suffocation 40	Homicide Firearm 55	Unintentional Pedestrian, Other 26	Unintentional Suffocation 68	Suicide Poisoning 337	Undetermined Poisoning 549	Homicide Transportation-Related 1,061	Undetermined Poisoning 761	Unintentional Unspecified 385	Unintentional Poisoning 722	Unintentional Suffocation 5,555
9	Adverse Effects 26	Homicide Other Spec., NEC 49	Unintentional Struck by or Against 25	Unintentional Firearm 39	Unintentional Fall 256	Homicide Cut/pierce 472	Unintentional Fall 647	Homicide Transportation-Related 644	Adverse Effects 384	Unintentional Natural/Env. 621	Suicide Poisoning 5,191
10	Unintentional Fall 23	Unintentional Natural/Env. 42	Unintentional Other Transport 22	Unintentional Pedestrian, Other 38	Unintentional Other Land Transport 250	Unintentional Drowning 374	Unintentional Drowning 462	Unintentional Suffocation 461	Unintentional Suffocation 381	Unintentional Other Spec., NEC 578	Unintentional Fire/burn 3,423

FIGURE 1 Ten leading causes of injury death by age group, with unintentional-injury deaths highlighted, 2001.

Note: Homicide and suicide counts include terrorism deaths associated with the events of September 11, 2001, that occurred in New York City, Pennsylvania, and Virginia. A total of 2,926 U.S. residents lost their lives in these acts of terrorism in 2001, of which 2,922 were classified as (transportation-related) homicides and 4 were classified as suicides.

Source: Vital Statistics Systems. Produced by Office of Statistics and Programming, National Center for Injury Prevention and Control, CDC.

- Good-natured competitions akin to simulator rodeos.

Analysis and Use of Commercial Vehicle Driver Data

Brenda Lantz

Databases

The Commercial Driver's License Information System is a distributed database with a central index that provides a link to each state driver records system. A driver license number and state are needed to query the database. It contains driver data such as date of birth, traffic convictions, and a standard code for identifying the seriousness of the convictions.

The Motor Carrier Management Information System is a centralized database maintained by FMCSA. It includes roadside inspection reports and can be queried by driver inspection violations, including out-of-service violations, moving violations, crash reports including a severity indicator, and carrier compliance review results. These and other databases are used to identify high risk in both carriers and drivers.

Past and Current Research Findings

In most states, when a commercial motor vehicle driver is given a traffic citation, the employing motor carrier is not identified on the citation. However, the state police in Indiana and Michigan try to identify the employing motor carrier and note it on the traffic citation. Linking driver citation data with the employing motor carrier showed that driver citation rates differed significantly among carriers and that higher driver citation rates for a carrier were also associated with higher accident rates for that carrier. A University of North Carolina study also revealed that serious driving violations were strongly correlated with crashes.

Unfortunately, there is no national traffic citation database or any standard for such state databases; therefore, using citation data to identify high-risk motor carriers is not currently feasible. However, analysis of the subset of citations that have been adjudicated shows that carriers with higher driver conviction numbers are also more likely to have a higher OOS rates, crash rates, and safety evaluation area (SEA) scores. A project is currently under way to examine the addition of this carrier–driver-conviction measure into the roadside Inspection Selection System (ISS) that is used by roadside inspectors nationwide. The ISS is used to help identify which vehicles and drivers to inspect based on prior carrier safety history.

Prior research shows wide variation in crash risk among commercial drivers. A relatively small percentage of drivers (10% to 15%) who crash account for a disproportionate percentage of total fleet crash risk (30% to 50%). Given this information, future research should begin to focus more on the driver level than on the carrier level.

In initial driver-specific analyses, results indicate that drivers with one or more traffic convictions in a given year have significantly higher crash rates in the subsequent year than drivers with no convictions. The analysis examined conviction and crash data for a subset of drivers who had experienced a roadside inspection during a specific 1-month period in 2003. The results showed a 38% to 51% increase in the likelihood of a crash for drivers with one or more convictions in the previous year. A current study is examining whether an overall driver performance–based indicator with a significant safety correlational and predictive ability can be developed. The study will examine whether specific types of driver violations or convictions are more highly correlated with future crash involvement; that is, the study will determine if moving violation, inspection, conviction, or past crash information is the best indicator of future crash involvement.

Research Needs

- Explore other potential driver databases, create new databases, or both.
- Identify data available at the state level or through other agencies.
- Develop a nationwide carrier-based system to link drivers to carriers and link the system to the current employer notification system project.
- Enable driver-based screening.
- Scan license data into a vehicle transponder.
- Develop a driver-based prioritization system.
- Develop a system for employer access to driver data to be used when new drivers are hired.

Commentary

Kevin Lewis

Three questions were used to stimulate discussion: What funding sources are available to pay for additional research and technology? What new technologies will significantly contribute to safety? If risky drivers are removed from the road, how will they be replaced?

Panel Discussion

Rebecca Brewster and Richard Clemente

Rebecca Brewster

Half of current drivers are recruited from the 35- to 54-year-old, white male cohort of the population, which is shrinking as a proportion of the population. Furthermore, drivers are increasingly required to multitask while in the cab of a truck because of the introduction of new technologies. Studies have shown that there is a fatigue cost to some of these technologies. Although technology improves alertness while driving, the fatigue cost comes later.

Research Needs

- Methods for identifying displaced workers who can be successfully retrained as drivers.
- Strategies for attracting and keeping young persons interested in driving as a career.
- Safety, security, and other strategies that will recruit more women into truck and bus driving.
- Methods that include drivers as part of the research design and testing of technologies.
- Marketing and implementation tools to encourage use of driver notification systems to focus efforts on the most risky drivers.

Richard Clemente

Two of the most serious issues associated with truck and bus drivers are (*a*) the aging factor, which must address not only a shrinking workforce but also the declining functional capacity that comes with the aging process, and (*b*) system capacity. If truck and bus travel doubles as predicted in the next 15 to 20 years, the road system, already over capacity in some areas, may not be able to support the load.

Audience Discussion

- Is training effective for reducing risk?
- How do you control for exposure when identifying the proportion of carriers, drivers, or both who are at high risk. SafeStat is flawed in that it doesn't control for exposure; hence, those with the highest mileage appear

to have a higher risk. (Committee note: SafeStat has flaws, but it uses exposure controls. The Safety Evaluation Analysis (SEA) scores are developed from rates, which are the incidence of crashes, violations, and so forth, normalized by vehicle miles traveled, number of drivers, and number of inspections.)

- The diversity issue must be embraced by incorporating language training into driver training programs and other initiatives to enable recruitment of new drivers. On April 1 the Commercial Vehicle Safety Alliance began to implement the OOS criteria on communication. Drivers must be able to communicate regardless of the native language. Implementation issues should be carefully examined.
- Drivers will be plentiful when they are adequately compensated (OOIDA) .
- Another option is to increase efficiencies in driver deployment.
- In addition to training, the system needs to introduce more intrusive safety management systems.

Safety Challenges Facing Tomorrow's Commercial Drivers and the Role of New Simulation Technology to Meet Them

Jerry Wachtel, Konstantin Sizov, Donald L. Fisher, Ronald Mourant, and Christopher M. Crean

Psychologists talk about road safety as a combination of three components: the driver, the vehicle, and the roadway environment. Although the distinctions were once clear-cut, they have become increasingly blurred as technology continues to facilitate the integration of functions and features. Satellite navigation brings road signs into the vehicle; antilock brakes, intelligent cruise control, radar braking, and the like shift previous driver demands onto vehicle systems. Roadway sensors and cameras enable real-time traffic information to be made available by radio, cell phone, or onboard computer screens.

It remains instructive to look at these components separately as contributors to safety, but there is concern that, for all that has been accomplished to bring down the crash and fatality rates in commercial vehicle operations (CVO) over the years, developments are moving in directions that will pose increasing challenges to truck and bus safety in the years ahead.

Vehicle Issues

As is the case in many other industries, the quality and reliability of the mechanical, electrical, and electronic equipment continues to improve to such an extent that it is rarely implicated in crashes. In fact, data show that only about 4% of all commercial vehicle crashes are caused by factors other than driver-related ones. Of course, the maintenance or operational status of the vehicle and its components is another matter, but that issue is beyond the scope of this paper.

Large trucks and motor coaches, like their four-wheeled siblings, are going high tech for better and for worse. Many truly beneficial features present in the latest technological interfaces are finding their way into road vehicles; however, because the industry that designs, builds, and markets this technology is driven not primarily by safety but by sales and marketing, it appears that this is merely the tip of the iceberg of new technologies that have the potential to affect the driver's task adversely in the years ahead.

Colker (2001) listed some of the technology soon (if not already) to be found in truck cabs: satellite navigation, lane departure alert systems, infrared night vision, and electronic air brake monitoring systems. He mentions other technologies that have potential not only as safety innovations but also as distractions to the driver, including onboard computers and e-mail. He does not mention all the devices such as MP3 players, DVD players with bright LCD screens, and other technologies still undoubtedly under development. The article discusses the Freightliner Productivity Computer, which fits into the radio dash slot and includes a processor that handles inputs from magnetic card readers, bar code scanners, digital cameras, game controllers, wireless communications, and, yes, a radio.

Why should there be concern about these technologies? The one-word answer is "distraction." For several years, the SAE Safety and Human Factors Committee has been wrestling with development of an SAE recommended practice titled *Navigation and Route Guidance Function Accessibility While Driving*. The document states, "Any navigation function that is accessible by the driver while a vehicle is in motion shall have a static total task time of less than 15 seconds" (SAE 2000). The document authors further elaborate:

> This recommended practice encourages interface designs that do not unduly distract drivers from the primary task of driving. Predictive estimation of crash risk resulting from driver distraction caused by any particular implementation…is difficult. However, it can be reasonably stated that if drivers are not looking at the road (i.e., looking inside the vehicle to operate a control or read a display), then the probability for a crash is increased.

The experts concluded that a longer static task time could unduly degrade safety, and most tasks commonly performed with existing devices take less than 15 s. In other words, they chose 15 s, at least in part because existing devices could already meet that criterion and because taking one's eyes off the road for up to 15 s was deemed safe.

At 65 mph, a vehicle travels more than ¼ mi (1,430 ft) in 15 s. At the same speed, it takes an 80,000-lb vehicle 525 ft to stop when traveling on a dry, level road including driver perception–reaction time and vehicle braking distance, according to the Oregon Trucking Association (OTA 2004). If the recommended practice were applied to large trucks and buses, it is possible that a driver could not bring a vehicle to a stop to avoid a crash with an object in the lane for 1,955 ft, or more than ⅓ mi. Is this not considered unduly distracting?

Additional concerns about the recommended practice are as follows:

- The criterion is based on static task time; that is, the test to determine if a device meets the criterion is performed in a laboratory setting, perhaps in a mockup or a parked vehicle, without any of the demands of a dynamic, or real-world, setting. A 15-s static task time could be considerably longer in a real-world setting.
- The test participants are given specific training in the task and five practice sessions before they perform—a situation different from what might be encountered in the real world with unfamiliar technology and lack of dedicated practice.
- The recommended practice applies only to navigation functions, that is, vehicle position and route guidance. It does not apply to phones, computers, music sources, video entertainment displays, communications systems, and other devices.

Roadway Issues

American roads, particularly the Interstate system, are among the best designed and safest in the world. However, a number of factors may reduce road safety in the years ahead. One challenge is that the U.S. roadway infrastructure is deteriorating because federal, state, and local budgets are ill-equipped to maintain it. A recent article in the *San Francisco Chronicle* described California governor Schwarzenegger's proposal to help plug the state's $9 billion budget deficit by diverting $1.5 billion in gasoline sales tax revenue earmarked for transportation safety (Gathright 2005). The consequences of these cuts could result in estimates of $700 per vehicle per year in damage from potholes, more than one dozen planned freeway expansion or widening projects put on hold, and $900 million in emergency highway repairs, including substandard bridges not being addressed. The domino effect is at work here.

Substandard roads and bridges at risk of collapse cause officials to restrict their use by heavier vehicles. These forced detours increase transit time, force these vehicles onto less appropriate routes, worsen congestion on such routes, and increase wear and tear on them. Deferred maintenance results in the need for emergency repairs in hastily assembled work zones. Highway work zones, even when planned and carried out with forethought, often occur in high accident locations. The risk to the motoring public increases dramatically when such work must occur on short notice, often at night, with more workers and more equipment to get the job done quickly. This situation is of particular concern because large trucks are substantially overinvolved in fatal crashes in work zones. An FMCSA report (2004) indicates that large trucks drove 7% of all U.S. vehicle miles in 2002 and included 3% of all registered motor vehicles; however, they represented 23% of fatal crashes in work zones.

Other highway contributions to safety risks include information overload that affects everyone. The emphasis in this paper is not just on ever-increasing traffic volumes, longer commutes, and incidents of road rage, although these are important factors. The focus is on the stream of information that confronts every driver every day on most major highways in the country. Although studies of distraction due to things such as roadside billboards have proved inconclusive over time, the newest billboard technologies may change that. The same large-screen video displays that grace major sports stadiums are slowly but surely coming to the roadsides. When combined with the consistent weakening of 40-year-old legislation that distinguishes between "on-premise" and "off-premise" commercial signage, the results may be dramatic. It is not beyond the realm of possibility that roadside television screens, highly visible even in bright daylight and standing 30 to 40 ft tall, could broadcast exciting plays from the local football game or the results of swimsuit competitions.

Recent studies have considered the effects of relatively small video signs displaying less than dramatic images and showed that drivers fixated on these signs longer than it was safe to do (Smiley et al. 2005). The newest technologies marry these video screens with technology that picks up radio waves from vehicles upstream of the sign. The billboards instantly display more "salient" advertising to approaching drivers. There seems to be little incentive for highway authorities to address the possible consequences of the spectacular outdoor advertising signs of the near future proactively. In fact, efforts to permit such advertising as part of the official highway signage system may be supported by highway authorities to fund badly needed sources of new revenue.

Even official highway signs can cause problems, such as the recent growth in electronic changeable message signs that warn of accidents, incidents, or road closures. Recently, these signs have been employed as part of the growing Amber Alert network, in which signs are used to alert motorists to possible child abductions. These signs can be highly effective in accomplishing the principal noble purpose. The unintended consequence is that the signs cause drivers to slow and read the message, which may cause significant backups. A recent study by the Minnesota Department of Transportation showed that 20% of drivers slowed between 2 and 13 mph to read an Amber Alert message (Blake 2003). It can be argued that slowing and resultant congestion may be a small price to pay when the message is significant, but these signs are also used for messages that are perhaps not so important. The irony is that freeway changeable message signs were introduced to alleviate congestion rather than aggravate it. Sudden slowing in dense traffic increases the crash potential for all vehicles, especially large trucks and buses that require long stopping distances. The entire issue of the design, placement, operation, and message content and display on signs is a human factors problem. Many studies have been completed, but many more are needed.

Driver Issues

Research and statistical analyses consistently support the long-held belief that a relatively small percentage of commercial drivers are associated with the greatest overall contribution to CMV crash risk. An enduring question is whether the risky behavior is trait based (i.e., enduring characteristics of the individual) or state based (i.e., temporary conditions).

Even though the data indicate that drivers of commercial vehicles are less often at fault in car–truck crashes than are the drivers of the passenger vehicles, the focus of this paper is on the overall reduction in commercial vehicle crashes. The issue in question is the professional drivers' abilities to avoid a potential crash even when such a crash might be triggered by someone else. The following characteristics address a series of significant driver-related issues.

Fatigue, Sleepiness, and Hours of Service

A recently completed study by the American Transportation Research Institute (ATRI 2002), sponsored by the Federal Motor Carrier Safety Administration (FMCSA), stated that 4.7% of commercial drivers (in a random sample of 400) had severe sleep apnea, 5.8% had moderate apnea, and 17.6% had mild apnea. The study found that age, gender, and obesity were major risk factors for sleep apnea among commercial drivers and that apnea was often undiagnosed and untreated. Also, it was found that tests of alertness were successful at detecting impaired performance due to apnea. Falling asleep at the wheel is not a problem of professional drivers alone. The Traffic Injury Research Foundation (TIRF) in Canada recently reported that one in five Canadians admitted to nodding off or falling asleep at the wheel at least once in the past year, and yet only 57% of the respondents to the same survey considered this to be a serious roadway safety issue (Beirness et al. 2005). The study cites data supplied by the National Highway Traffic Safety Administration (NHTSA) showing that drowsy driving is responsible for 100,000 crashes, 40,000 injuries, and 1,550 fatalities annually. The causes of such sleepiness are not surprising. Fewer hours of sleep and poor quality of sleep were the most important contributors. When figures for sleepiness are combined with those for sleep apnea, alarming statistics are revealed. Again, as stated earlier, even though the professional driver may not be at fault when another driver loses control after falling asleep at the wheel, it is the crash itself—not the fault finding—that is of concern.

In this context it is of great concern, though perhaps of little surprise, that proposals such as the recent "Wal-Mart amendment"—which would increase the professional driver's work day still further and contribute to even greater fatigue problems—could be put forward. This proposal was withdrawn by its sponsor after fierce opposition. But safety advocates must guard against others coming along.

Driver Age

Two years ago FMCSA rejected a petition from the Truckload Carriers Association (TCA) to conduct a pilot program that would have enabled young drivers (between 18 and 21) to operate commercial motor vehicles in interstate commerce. Despite program components that included screening, training, and on-the-job apprenticeship, the program had the potential to compromise safety seriously: the agency did the right thing.

Despite 30 years of effort, the young driver crash problem has not been solved in passenger cars. Putting such drivers behind the wheel of a large truck or motor coach does not make any sense. A combination of two factors—inexperience and immaturity—conspires to keep their crash rate high. Although the former can be addressed by education and training, by programs such as graduated licensing, and perhaps, in commercial vehicle operations, by apprenticeship and on-the-job training, no one has found a way to accelerate the maturation process. In efforts to lobby against the proposal to lower the legal driving age for the CDL, the Advocates for Highway and Auto Safety (2001) provided a good overview of what is known about the safety of young, novice drivers. It is worth reviewing for further information on this subject.

Some interesting light was recently shed on the maturation issue by Jay Giedd, a neuroscientist at the National Institute of Mental Health. What Giedd and his colleagues have learned as a result of extensive MRI brain scans of healthy teens is that the prefrontal cortex, that "part of the brain responsible for planning, judgment, and self-control," is one of the last parts of the brain to mature and is not fully developed until age 25. Conversely, the amygdala, the part of the brain that mediates fear, emotion, and gut reactions, develops earlier, and teens "tend to depend on (it) when making decisions" (Kersting 2004). Such studies are beginning to provide the physiological and psychophysiological data to support the understanding of young, novice driver behavior that has long been recognized, and it does not augur well for a reduction in the CDL age. Nonetheless, this issue, like that of hours of service, likely will be raised again.

Criterion Problem: What Makes a Safe Driver?

When road safety experts talk about unsafe drivers, they typically discuss three different ways to distinguish this group from safe drivers: accident rate, violation history, and performance on an official road test. Although these may be the best measures available, they lack predictive ability for several reasons.

First, crashes are relatively rare events, and they are not normally distributed within the population. Generally police reports must be relied on to analyze crashes. Police reporting across the 50 states, and even within specific jurisdictions, is quite variable; therefore, interrater reliability is a problem. Second, because of demands on police officers' time, reports are sometimes taken in shorthand fashion and it is often convenient to identify the cause of an accident as driver inattention (or some other factor) rather than digging deeper to seek root causes. Finally, because of other imperatives, police officers generally seek to find fault—to identify the driver who "caused" the accident. Although this may be convenient for the issuance of summonses and for possible litigation, it does little to help investigators and researchers unearth the true cause or causes, which are often not straightforward. FMCSA's goal should not be to reduce at-fault crashes by commercial drivers; it should be to reduce crashes involving commercial drivers regardless of fault.

Violation histories are also suspect, since it has been shown that there are high-violation drivers who are underrepresented in crashes, and high-crash-involved drivers who are rarely cited for a moving violation. Finally, road test scores tend to be used as criteria for safe driving. Although this is less of a problem with the CDL because of uniform requirements across the states, it is a serious problem for the general driving population because there are almost as many variations in the road test as there are state DMVs. Thus, it becomes quite clear that different tests may well be measuring different behaviors; therefore, they are not readily comparable. Worse, with few exceptions, the behaviors that they do measure are not closely related to the real-time dynamic challenges of driving.

In short, a criterion problem exists when it comes to distinguishing safe from unsafe drivers and becomes a significant, practical issue when new and better training and testing methods are developed. If the measure of success is not clear, confidence in training and assessment programs will be lacking.

Other ways to look at criteria for safe driver performance in the commercial or professional setting offer promise as models to assess training and assessment effectiveness. The first is cost. In the San Francisco Bay Area in California, the Association of Bay Area Governments (ABAG) is an umbrella organization that, among many other functions, performs driver training for police, fire, emergency rescue, parks and recreation, and public works drivers of their member city and county governments. Their training subsidiary, ABAG-PLAN, has shown close to a 20% reduction in accident claims in the first 3 years of operation of its mobile driving simulator training program and has returned $3.4 million in equity through lowered insurance premiums and other related cost savings over the same time period. During this period, ABAG-PLAN used its mobile driver training unit to train 1,130 police officers, 66 firefighters, and 223 city employees (Eash-Ladd 1997). Because the trailer-mounted mobile simulation facility visits the locations in which training is needed, these throughput numbers are substantially higher than might be the case for permanent simulator installations.

A second novel approach to assessing safe driver performance is the comprehensive analysis and information system developed for FMCSA by the Volpe Center (FMCSA 2004). The SafeStat module includes components known as SEAs, which obtain, integrate, and analyze data from multiple sources to paint a picture of safety far more detailed than has traditionally been available. For example, in the driver safety evaluation area, data are available on moving violations, driver roadside inspections, and violations of driver-related acute and critical regulations discovered during compliance reviews. Part of the strength of this system is that the measures are weighted, for example, by severity and recency, and are then compared with scores obtained by other carriers within the same region. For the accident safety evaluation area, calculations are based on state-recorded crash data, carrier-reportable crash data, and other information, again weighted by factors such as severity and recency, to determine a carrier's overall crash experience relative to that of its peers. As this is written, the accident SEA has been deleted from the overall evaluation because of the variability in one of its key measures, the state crash reports.

Two other means could greatly increase understanding of safe drivers and immeasurably improve the ability to develop, conduct, and evaluate training and assessment programs. Each of these methods has been used with great success in the field of commercial aviation, each is relevant and appropriate to commercial driving, and each has met with considerable resistance in the field of ground transportation. The first is confidential near-miss reporting; the second is onboard crash data recording. If the commercial vehicle operations industry could agree to implement these programs on a fault-free, non-punitive basis as is done in the aviation community, great strides could be made in understanding and solving issues of driver safety.

The prospective benefits of these approaches are straightforward but essentially beyond the scope of this paper. In summary, for every crash that occurs, there are countless near misses or traffic conflicts, in FHWA language, in which a crash is narrowly averted because of the actions of one or more of the drivers potentially involved. An understanding of these near-misses could provide valuable data about crash causation and avoidance and could contribute meaningful input to improve driver training and testing.

In the field of commercial aviation, the Aviation Safety Reporting System has been used by the FAA for many years. It is operated by the National Aeronautics and Space Administration to ensure independence and confidentiality. It is rare to find an aviation safety expert who does not find this system invaluable. Similarly, aircraft-type flight data recorders are increasingly available for surface vehicles. They can record vehicle dynamic behavior and control inputs in the minutes and seconds before a crash or near miss.

Most professional truck and bus drivers are extremely competent and at little risk of crashing due to routine daily threats by other drivers including those who cut them off, merge improperly, drive in their blind spots, tailgate, and so forth; therefore, the risk of crashing and the need to train and test for such risk are greatest when the professional driver is confronted with relatively rare events. As is the case with operators in many other industries, the knowledge, skills, and abilities (KSAs) used for routine performance are perhaps overlearned, but it is those KSAs that are rarely called on that contribute to the severe crashes and for which training and preparation are most needed. It is for this reason that near-miss reporting and black box recorders may prove helpful, and it is for this same reason that training through simulation is vital (see Wald 2002).

Simulation: Past and Present

Driving simulators have been around for more than 50 years (Wachtel 1995), and they have had proponents and detractors nearly that long. Those who have spent their careers working with simulators and advancing the state of the art have been saying for 30 years that simulation's time has finally come for driver training and testing. Yet this technology is still on the periphery as it relates to driver assessment, preparation, and training. Why?

This question is especially pertinent when it is realized that simulation has been successfully used for training airline pilots, nuclear power plant operators, astronauts, military personnel, merchant marine ship captains, and railroad engineers for decades. In fact, the first time that a pilot takes control of the airplane, it is quite possible that he or she will never before have actually flown that type of plane. Pilots can fully qualify and be licensed in an FAA-approved flight simulator. Furthermore, the people operating nuclear power plants are qualified in the same manner. They may be at the controls of a plant for the first time, having completed their training and their licensing requirements on a simulator approved by the U.S. Nuclear Regulatory Commission. There are four principal reasons why simulation has not yet been mainstreamed for commercial vehicle operator training and licensing:

1. Cost. Traditionally the cost of simulators has been high and the cost of the truck or bus was (relatively speaking) low. Thus, the argument went, why not use the real vehicle?
2. Realism. Creating a realistic simulation is surprisingly difficult for road vehicles, and all drivers expect highly realistic depictions of the real world, despite the fact that there is little evidence to show that higher realism (known as physical fidelity in the simulator world) is

necessary for training or testing (Hays and Singer 1989). In other words, the people who make the decisions about whether to use simulators in their programs often take the position that if the simulation doesn't look and feel like the real thing, it can't be any good, despite considerable empirical evidence to the contrary. Surprisingly, it is far easier to create a convincing simulation for aircraft, spacecraft, ships, trains, and nuclear power plants than it is for cars, trucks, and buses. This argument is beginning to fade as vehicle simulators become more sophisticated and as the simulation community does a better job of communicating with the training and testing community that what is important in simulation is not physical fidelity but functional fidelity and that the measure of simulation success should not be whether the simulation looks like the real thing but whether behaviors measured on the simulator map those in the real world.

3. Sickness. It has been said that simulator sickness is the single greatest impediment to the acceptance of driving simulation for training and testing (Hein 1993). Simulator sickness is a complex phenomenon that, at its most basic, is a result of a psychophysiological cue conflict within the driver of the simulator that is caused by a disparity in the cues being sent to the body by the simulator's visual system and its motion (or lack of motion). Sickness can affect participants in any simulator regardless of cost or sophistication, and there is evidence that less costly, less sophisticated simulators suffer less from the problem than their more advanced brethren. More is being learned about the causes of this phenomenon every day, and progress is being made toward reducing, if not eliminating, it. Nonetheless, some simulator sickness seems to be inevitable, because there are great individual differences in susceptibility.

4. Part versus whole task. Driving an intercity bus or over-the-road truck is a complex task. As in driving any vehicle, there are three major components to the job. Different researchers have characterized these tasks in slightly different ways. At the most basic is the vehicle control—steering, braking, gear shifting, mirror use. At the next level is the ability to perform within the traffic stream—speed control, lane position, passing, merging, and negotiating in tight spaces such as terminals. At the highest level is navigation and planning—route selection, dealing with weather, traffic or road conditions, and response to emergencies. In trucks and buses, these demands exceed those of a typical passenger vehicle. The reasons include the obvious ones of vehicle size and weight, but also the task may be mediated by factors such as changing vehicle dynamics and handling characteristics with different loads, which place far greater attentional demands on the driver. In the past, simulation was criticized because only the largest, most expensive and sophisticated devices could support some of these unique requirements. Backing, in which truck and bus drivers must rely on their mirrors, and handling characteristics under different combinations of load and cargo are examples of challenges that few simulators could meet. This should not imply that simulation should be discarded as a viable training and testing medium. It does mean, however, that simulation is part of an integrated multifaceted approach to training and assessment rather than a stand-alone solution to every need.

Simulation: The Future

There is a bright future for simulation in the training and assessment of bus and truck drivers, and it lies not with stand-alone, costly, high-fidelity simulators with 180- to 360-degree fields of view and six degree-of-freedom motion platforms. This is not to suggest that there isn't a place for these devices, but they are best reserved for research applications, and for the design and development of scenarios that can then be run on more affordable simulator, and for the possible highly specialized training of drivers for rare, potentially catastrophic events.

Rather, the future is in small, relatively low-cost, part-task simulators that can be available wherever and whenever needed. Such simulators can be located in the depots of truck and bus companies, at truck stops and highway rest areas, and in other locations that professional drivers frequent. These simulators could be placed into service as part of a larger, redesigned driver training and assessment environment that provides financial, psychological, and functional incentives for their use.

A situation may be visualized in which CDL drivers must periodically demonstrate their KSAs to maintain their license. One can imagine that drivers could demonstrate to FMCSA their level of competence by an online, up-to-date system in which these performance criteria are thought of as not unlike the continuing education units (CEUs) used in the medical profession and others in which it is expected that practitioners maintain knowledge of the latest techniques and the skills to carry them out. Well-developed KSAs can be presented and measured by these low-cost, widely deployed simulators. During the course of a given license renewal cycle (e.g., 3 years), a driver could obtain CEUs by visiting any of the simulators on this network and performing the requisite activities in the (online) training log book. Any driver could also use any of these simulators at any time to practice, to prepare for the test, to study a particularly dangerous stretch of road ahead, or to keep skills sharp. Today's simulators and their programs are sufficiently sophisticated that a given simulator can have a wide variety of alternate forms of each scenario so that a driver would not be able to practice a particular scenario and be assured of passing the test.

What is the real benefit to be gained from this scenario? It is the practice and consequent comfort gained in the performance of those KSAs needed for judgment, decision making, and behavior in those rare, emergency events that lead to the loss of lives and property. Driving every day in all kinds of traffic, on all types and conditions of roads, with different passenger and cargo loads provides truck and bus drivers with all they need to handle 99% of the situations likely to be encountered. But it is the 1%—for example, black ice on the two-lane mountain road, the sudden appearance of the leading edge of a dense fog bank, the drunk passenger car driver who loses control and cuts across the path of the commercial vehicle, the improperly secured load that suddenly shifts during a high-speed curve—for which drivers may be unprepared and ill-equipped. And here simulation can come into its own.

This begs the question of why simulation is needed. The answer is because drivers cannot be prepared for these types of situations in any other way. They cannot be fully taught or allowed to practice these events in actual vehicles on test tracks or controlled courses, although some have tried. These KSAs cannot be taught in a classroom because first-hand experience is a key condition. Furthermore, they cannot be taught through videos or films because these delivery methods are not interactive. Simulation shines in these cases, where it can provide the proper learning environment, that is, an environment in which making a mistake and crashing is not failure but part of the learning process. It is even possible to incorporate such simulation into friendly competitions between professional drivers—a sort of simulated rodeo in which drivers compete for prizes and peer recognition.

Several years ago a paper presented at an American Association of Motor Vehicle Administrators (AAMVA) workshop with the head of driver licensing services for the Oregon DMV (Nunnenkamp and Wachtel 1992) described a pie-in-the-sky concept of a series of kiosks in public places (shopping malls, libraries, etc.) that would look not unlike the old Polaroid photo booths. These booths would contain small, part task driving simulators that would be linked by phone lines to the local motor vehicle bureau (and the credit card agency). The idea was born out of two parallel developments of that time: the need to network a series of driving simulators for use in law enforcement training and a concept being promoted by AT&T for remote, automated driver's license renewal. The concept was that when drivers' licenses were up for renewal, citizens would get a notice in the mail to report to any simulator kiosk for testing. They would go to the mall, insert the notice into the machine, and insert a credit card, which would (*a*) verify their identity and (*b*) deduct the fee for the renewal test. They would sit in the simulator, close the door, and take the test. Given the technology available (it is dramatically better now), they could take a vision test, a rules-of-the-road test (and learn about any changes in laws that might have taken effect since their previous license was issued), and the road test, all on the simulator and in complete privacy in about 10 min. If they passed, the new driver's license was issued on the spot. If they failed, the old license was returned to the individual, together with instructions to report to the DMV for traditional retesting. Aside from the technological breakthroughs that this provided, there were numerous other benefits, of which the following are directly applicable to commercial vehicle operations:

1. A driver could practice at any time simply by visiting the kiosk and inserting a credit card. An individual who was concerned about driving abilities in advance of the required road test could practice any or all of the skills that caused concern.
2. Total privacy was assured; that is, no official was looking over the shoulder of the individual at the wheel.
3. The kinds of skills and capabilities that could be practiced and evaluated are the ones that simply cannot be practiced or assessed through other means.

Although this idea has not progressed beyond the concept stage, it may be the perfect application of new simulator technology for professional truck and bus drivers. A number of simulators currently in the marketplace could be readily applied to this purpose, and this is a viable and exciting possibility for the future of professional truck and bus driver licensing and training programs.

Another promising development in simulator technology with potential applications to commercial drivers is based on the success enjoyed by ABAG. One reason for this success is throughput. ABAG simulators are mobile, and they can be brought to any member's training center or any other site of interest. This provides valuable savings of time otherwise lost from work, travel costs to the training facility, and availability of drivers. In other words, if driver training is a good thing, it is far more cost-effective to train many drivers on a subset of key KSAs than it is to train fewer drivers on a broader array of behaviors.

Currently a new simulator that provides the potential for two benefits not previously possible is being tested. First, the simulator is totally portable; the components fit in the trunk of a full-size car. Second, it permits the actual vehicle of interest to be driven within the simulated world and thus enhances face validity and improves transfer of training from the simulator to the real world. This simulator has been tested with novice and older drivers on passenger vehicles, and the results are encouraging. The steering ramps at the heart of the system have been designed to withstand the weight of a truck or bus, but these vehicles have not yet been tested on the simulator. It is hoped that such testing will be reported on in the near future.

REFERENCES

Advocates for Highway and Auto Safety. 2001. *Fact Sheet: A Deadly Mix—Young Drivers and Large Trucks*. Washington, D.C.

American Transportation Research Institute. 2002. *Prevalence of Sleep Apnea Among Commercial Truck Drivers*. Alexandria, Va.

Beirness, D. J., H. M. Simpson, and K. Desmond. 2005. *The Road Safety Monitor 2004: Drowsy Driving*. Traffic Injury Research Foundation, Ottawa, Ontario, Canada.

Blake, L. 2003. Freeway Message Boards Warn About Slowdowns—and Perhaps Cause Them. *Minneapolis Star Tribune*, August.

Colker, D. 2001. Truckers Hit High-Tech Road: On-Board Computers, Satellite Navigation and Night Vision Are Steering Big-Rig Drivers Toward the Future. *Los Angeles Times,* October 11, p. T1.

Eash-Ladd, D. 1997. *Police Mobile Training Unit Annual Report*. Association of Bay Area Governments–ABAG-PLAN Corporation, Oakland, Calif.

FMCSA. 2004. *2002 Large Truck Crash Overview*. Report FMCSA-R1-04-022. U.S. Department of Transportation.

FMCSA. 2004. *SafeStat Online*, Run Version 8.6. U.S. Department of Transportation. http://ai.volpe.dot.gov/mcspa.asp.

Gathright, A. 2005. State Puts Drivers in Jeopardy, Critics Say. *San Francisco Chronicle,* February 5, pp. B1, B5.

Hays, R. T., and M.J. Singer. 1989. *Simulation Fidelity in Training System Design: Bridging the Gap Between Reality and Training*. Springer-Verlag, New York.

Hein, C. M. 1993. Driving Simulation: Six Years of Hands-On Experience at Hughes Aircraft Company. *Proc., Human Factors and Ergonomics Society 37th Annual Meeting*, pp. 607–611.

Kersting, K. 2004. Brain Research Advances Help Elucidate Teen Behavior. *APA Online Monitor on Psychology,* Vol. 35, No. 7, July–August.

Nunnenkamp, P. W., and J. A. Wachtel. 1992. A "Blue Sky" Approach to the Future of Driver Qualification. Presented at American Association of Motor Vehicle Administrators. Driver Licensing and Control Workshop, New Orleans, La.

Oregon Trucking Association. 2004. *Stopping Distances for Cars Vs. Trucks*. http://www.ortrucking.org/stopping.htm.

Smiley, A., B. Persaud, G. Bahar, C. Mollett, C. Lyon, and T. Smahel. 2005. Traffic Safety Evaluation of Video Advertising Signs. In *Transportation Research Record: Journal of the Transportation Research Board, No. 1937*, Transportation Research Board of the National Academies, Washington, D.C.

Society of Automotive Engineers. 2000. *SAE Recommended Practice: Navigation and Route Guidance Function Accessibility While Driving*. SAE 2364. Detroit, Mich.

Wachtel, J. 1995. A Brief History of Driving Simulators. *TR News,* No. 179, July–August, pp. 26–27, 45.

Wald, M. L. 2002. Automakers Block Crash Data Recorders That Could Save Lives, Critics Say. *New York Times,* December 29.

Analysis and Use of Commercial Vehicle Driver Data

Brenda Lantz

The majority of prior research and analysis points toward driver-related factors as the main cause of most commercial vehicle–related crashes. Preliminary results from the FMCSA Large Truck Crash Causation Study reveal that the critical reason for crashes is driver-related in more than 90% of the cases. Therefore, future research must provide a greater concentration on the commercial driver to have the most profound impact on the number of crashes.

Previous research efforts have used commercial driver traffic conviction data as a data source to identify poor-performing drivers and the carriers that employ them. The research to date in this area and how future research should examine additional ways to create driver-based indicators by using conviction data and other driver-specific data are presented here. Potential data sources are described. Future research should also determine ways to collect and maintain efficiently and effectively data that tracks a driver's performance. If feasible, these data should be shared not only with enforcement agencies but also with potential employers of the drivers. In addition, ideas for using these data and indicators in future enforcement and carrier safety management programs are explored.

Previous Research

Several previous studies have utilized commercial driver information for analysis.

Carrier-Based Research

One of the initial studies that linked commercial driver information to the carriers that employ them was the Driver/Carrier Data Relationship Project. This study examined 1994 traffic citation data from two states, Indiana and Michigan. In most states, when a commercial motor vehicle driver is given a traffic citation, the employing motor carrier is not identified on the citation. However, the state police in these two states try to identify the employing motor carrier and note it on the traffic citation. Thus, driver citation data could be linked to the employing motor carrier for this analysis. The main conclusions from this study were that driver citation rates differ significantly among carriers and that higher driver citation rates for a carrier are also associated with higher accident rates for that carrier (AAMVAnet, Inc. and Keane Federal Systems 1997).

The University of North Carolina has also completed work based on North Carolina carrier data that revealed that "serious driving violations" were a strong predictor of crashes. Once again, the analysis is at the carrier level and the conclusions are regarding the relationship between the carrier's driver violations and the carrier's crash rates (Hughes n.d.).

Unfortunately, there is no national traffic citation database or any standard for such state databases. In addition, only a few states record the U.S. Department of Transportation (DOT) carrier number on traffic citations, and these states have problems with accurate identification of the employing motor carrier by state or local police officers when issuing a traffic citation. Thus, without such a national program, it is not currently feasible to use citation data nationwide to identify higher-risk motor carriers.

Therefore, an analysis was conducted to examine whether a correlation exists between traffic conviction data (the subset of citations that have gone through the adjudication process) that are accessible through the Commercial Driver's License Information System (CDLIS) and high-risk motor carriers linked to drivers through inspection and accident reports contained in the Motor Carrier Management Information System (MCMIS).

Specifically, the carrier–driver–conviction data (CDC) study concluded that linking driver conviction data from the CDLIS to the employing motor carrier provides an additional method to identify those motor carrier companies with safety problems. A CDC measure based on the average number of traffic convictions of drivers associated with carriers is significantly correlated with the carriers' OOS rates, crash rates, and SafeStat SEA scores. Carriers with higher (worse) driver conviction measures are also more likely to have higher OOS rates, crash rates, and SEA scores (Lantz and Blevins 2001).

Building on the CDC study, a project is currently under way to examine the addition of this CDC measure into the roadside ISS, which is used by roadside inspectors nationwide. The ISS is used to help identify which vehicles and drivers to inspect on the basis of prior carrier safety history (Lantz et al. 2004).

Driver-Based Research

Prior research conducted by the Virginia Tech Transportation Institute has identified that "commercial drivers differ greatly in their levels of crash risk, and that a relatively small percentage of drivers (10–15%) account for a disproportionate percentage of total fleet risk (30–50%)" (Knipling et al. 2004). Given this finding, future research should begin to focus more on the driver level rather than the carrier level.

In initial driver-specific analyses conducted by the author, results have indicated that drivers with one or more traffic convictions in a given year have significantly higher crash rates in the subsequent year than drivers with no convictions. The analysis examined conviction and crash data for a particular subset of drivers who had a roadside inspection during a one-month period in 2003. The results illustrated between a 38% and 51% increase in the likelihood of a crash for drivers with one or more convictions in the previous year.

The author is also currently involved in a research project sponsored by the American Transportation Research Institute that is examining whether an overall driver performance–based indicator with significant safety correlational and predictive ability can be developed. In addition, the study will examine if specific types of driver violations or convictions are more highly correlated with future crash involvement; that is, the study will determine if moving violation, inspection, conviction, or past crash information is the best indicator of future crash involvement.

Data Sources

Commercial Driver's License Information System

CDLIS was created in response to the Commercial Motor Vehicle Safety Act (CMVSA) of 1986. It is the only existing nationwide source of CDL drivers' traffic conviction data. CDLIS is a distributed, relational database that provides a linkage between the various state driver records systems using a central index.

CDLIS has been in full operation since April 1992. The central index serves as a clearinghouse that each of 51 jurisdictions (the 50 states and the District of Columbia) can check before issuing a CDL to ensure that no other state has issued one to that driver and that the records for that driver's CDL will be transferred to the new state where the driver is applying. It also assists states in reporting out-of-state convictions to the licensing state, where they are made part of the driver's record.

Motor Carrier Management Information System

FMCSA maintains a centralized database of carrier-based information regarding accidents and roadside inspections of commercial motor vehicles and drivers. This information is entered by states into their local SAFETYNET information system. The states then transmit relevant data for carriers electronically to FMCSA's information system (MCMIS).

Most accident and roadside inspection reports in MCMIS identify both the driver and the motor carrier for whom the driver was working at the time of the accident or roadside inspection. Approximately 3 million roadside inspections and 100,000 accidents are reported each year.

MCMIS also contains census information regarding each motor carrier, such as address, number of power units, number of drivers, and cargo carried.

Future Research Recommendations

Prior studies have shown a clear reason to continue to focus efforts on the driver to achieve significant accident reduction. Beyond the continued research into ways to use current data sources, such as CDLIS and MCMIS, research should either explore other existing databases of driver information or determine methods to create new databases. For example, if many enforcement efforts continue to be carrier-based, examining the potential for establishing a nationwide system of linking drivers to their current carrier employers would be valuable. This system could perhaps be combined with the current Employee Notification Service project sponsored by FMCSA, which will be pilot tested in the next year. Such a system would enable the use of driver information as another indicator to focus on particular carriers for enforcement activities.

If technology evolves to the point of enabling driver-based screening along the roadside at highway speeds (perhaps through the scanning of the driver's license into a vehicle transponder), research should be completed to develop driver-based prioritization systems.

From the carrier standpoint, information regarding a potential new driver's past inspections, violations, crashes, and convictions should be made available to carriers so they can make an informed decision during the hiring process. Future research should examine the development of such a system to allow carriers, once they have received the potential new driver's consent, to access this information.

References

AAMVAnet, Inc., and Keane Federal Systems. 1997. *Driver/Carrier Data Relationship Project: Phase II Report*. FMCSA, U.S. Department of Transportation. Available at dms.dot.gov.

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

Knipling, R., E. C. B. Olsen, and T. D. Prailey. 2004. *Individual Differences and the "High Risk" Commercial Driver*. Federal Motor Carrier Safety Administration Tech Brief. FMCSA, U.S. Department of Transportation. Available at http://www.fmcsa.dot.gov/safetyprogs/research/briefs/high_risk_commercial_driver.pdf.

Lantz, B. M., and M. W. Blevins. 2001. *An Analysis of Commercial Vehicle Driver Traffic Conviction Data to Identify High Safety Risk Motor Carriers*. Upper Great Plains Transportation Institute Publication. North Dakota State University. Available at http://www.ugpti.org/research/carrier/pdfs/CDC09_10_01.pdf.

Lantz, B. M., J. Loftus, and T. Keane. 2004. Development and Implementation of a Driver Safety History Indicator into the Roadside Inspection Selection System. Presented at 30th International Forum on Traffic Records and Highway Information Systems. Available at http://www.ugpti.org/tssc/projects/drivesafe.php.

Vehicle Design and Technology

D. M. Freund, *Federal Motor Carrier Safety Administration*
S. J. Shaffer, *Battelle Memorial Institute*
L. W. Loy, *Federal Motor Carrier Safety Administration*
L. W. Minor, *Federal Motor Carrier Safety Administration*
Peter Sweatman, *University of Michigan Transportation Research Institute, Provocateur*
Timothy Morscheck, *Eaton Corporation*
Richard Beyer, *Bendix Commercial Vehicle Systems LLC*
Margaret Sullivan, *PACCAR, Inc.*
V. K. Sharma, *International Truck and Engine Corporation*
Robert Clarke, *Truck Manufacturers Association, Moderator*

FUTURE SCENARIO

Over a 5- to 20-year horizon, CMV design will continue to evolve incrementally. The casual observer will perceive CMVs as similar to today's vehicles, but they will bear much less resemblance to their forebears:

- CMV brakes will be lighter and more durable and will require less routine maintenance. CMV tires will be more durable and will be able to better maintain their set target pressures.
- Some CMVs will be equipped with aerodynamic accessories to adjust airflow around the vehicle: its fuel economy will improve, and, when needed, turbulence to reduce stopping distance will be increased.
- The complexity of electronically controlled engines and drivetrains, brakes, tire pressure management, and driving environment management systems (such as lane-keeping and headway management) will likely tax the abilities and availability of skilled technicians.

RESEARCH NEEDS

Brakes

- Technological innovation to improve brake reliability and maintainability.
- Definition of the key parameters to be monitored and displayed.
- Appropriate degree of performance decrement at which to notify the driver and perhaps the level at which the vehicle will not allow itself to be driven.
- Enhancement of the robustness, accuracy, and reliability of these integrated systems.

Tires

- Enhancement of the safety performance of tires by allowing them to provide more predictable traction levels on wet, slick, and dry roads so they perform as interactive components of the CMV's stability and control system.
- Tire pressure management systems that accommodate a large pressure range.
- Reliability of these systems over the working life of tractors and trailers.
- Development of cost-effective tire self-preservation systems that will allow the CMV to be driven safely to a repair facility.
- Ways to ensure that drivers using CMVs equipped with these new systems and technicians responsible for maintaining them are able to safely transfer and upgrade the skills acquired from working with conventional vehicles.

Propulsion Systems and Fuels

- Design of fueling systems and fuel storage compartments of hybrid and non-petroleum-fueled CMVs to ensure safe operation and maintenance.
- Development of hydrogen-based fuels (including hydrides) for the next generation of CMVs, which are likely to use hydrogen in the form of metal hydrides and other compounds in fuel cells.
- Development of fuel-storage media and delivery systems that are both crashworthy and safe to transport, store, and use.

Aerodynamic Devices

- Optimized design and placement of aerodynamic devices to take full advantage of the nature of smooth and turbulent airflows around CMVs to achieve mutually beneficial outcomes.
- Improved durability and capability of retrofit for both tractors and trailers.
- Demonstrated cost-effectiveness.

Driver–Vehicle Interaction

- Creation of driving environments that provide a comfortable, alertness-enhancing, and crashworthy workspace to promote the driver's efficient and effective management of driving task elements through improved design of displays and controls.
- Improved driver situational awareness of events inside and outside the CMV without causing cognitive overload.
- Studies to address the potential for autonomous control if the driver becomes unable to control the CMV.
- Update of anthropometric research conducted in the 1980s and 1990s to account for long-term trends of increasing stature, changes in the ethnic and gender composition of the workforce, data errors, and lack of comprehensiveness of the prior studies.
- Enhanced alertness-promoting properties of the physical environment, such as postural support, temperature of air and contact surfaces, improved lighting, and reduced glare.
- Improved design (including sensor selection and signal processing and communication), reliability, and consistency of performance and appropriate use in driver self-assessment or motor carrier oversight.
- Development of effective methods to train or retrain drivers who have never used the new devices or for those who are accustomed to conventional devices, such as mirrors, to use them safely.
- Any device that could transfer control from the driver, such as full active control of steering or foundation brakes, which is critically needed to predict and, it is hoped, prevent introduction of risk-homeostasis.
- Assurance that changes to the materials and structural designs of CMVs, including their cabs and sleeper berths, provide protection to the driver and other occupants in the event of collision, rollover, submersion, and fire.

Crash Mitigation: Vehicle Aggressiveness

- Optimization and transfer of impact energy-absorbing technology from infrastructure devices to vehicles.
- Optimized use of advanced materials in CMVs to develop efficient and cost-effective manufacturing methods and demonstrate long-term benefits.

Maintenance Tools

- Development of sensor firmware and diagnostic software for rapidly and accurately diagnosing both electronic and mechanical malfunctions and for mistake-proofing maintenance and repair procedures.
- Development of methods for confirming the safe status of technologically advanced CMVs, both when in a prescreening mode (CMV traveling at or near highway speed) and when the CMV is stationary.

COMMENTARY

Peter Sweatman

Five crash types represent 55% of all accidents:

- Turn across;
- Sideswipe same direction, other vehicle encroaches;
- Sideswipe same direction, truck encroaches;
- Rear-end strike (high severity); and
- Run off the road (high severity).

Future Scenario

- Increase in the demand for freight transportation will increase truck miles.
- Change in mix of trucks:
  - –Long-distance vehicles will be larger, but the number of them will increase at a lesser rate than that for other trucks.
  - –Local and regional truck haulers will increase at a greater rate.

- Per capita car miles will increase but at a lesser rate than truck miles.
- The ratio of trucks to private vehicles will be higher.
- More aggressive driving of larger, heavier private vehicles will increase exposure to crashes.
- Aggressive driving and denser traffic will occur around trucks.
- Key accident types to address will be
  – Turns at intersections,
  – Encroaching paths (already more than 20% and increasing),
  – Rear-end crashes,
  – Head-on (other vehicle encroaching), and
  – Run off the road.

Research Needs

In terms of truck communications research, safety applications should be based on accident types, such as rear-end strikes at work zones, unexpected congestion and intersections, rollover on curves, lane departure warning and assist, assisting and protecting lane changes, adaptation of truck and other vehicle speeds to traffic conditions, and electronic separation of trucks and other vehicles.

Truck safety research in the 21st century should focus on the following:

- Technologies addressed and evaluated in groups rather than singly.
- Advanced safety systems to help drivers of trucks and other vehicles.
- Intervehicle communication to reduce conflicts between trucks and other vehicles.
- The development of truck-specific safety applications for VII, targeting key accident types.
- Risk measurement based on enriched exposure data and including movements of other vehicles.
- Smarter driving of safer vehicles.
- Study of distribution vehicles and other vehicles' behavior around these vehicles.

Panel Discussion

Timothy Morscheck, Richard Beyer, Bendix Margaret Sullivan, and V. K. Sharma

Current Research

The 21st Century Truck Partnerships is a collaborative effort among truck, engine, and hybrid system manufacturers and government agencies such as the U.S. Departments of Transportation, Energy, and Defense and the Environmental Protection Agency to improve safety and fuel efficiency while maintaining planned emissions reductions. Examples of the current focus include braking, stopping distance, rollovers, driver aid systems, visibility, and tire performance.

As could be expected, research conducted on the vehicle side tends to be more oriented toward immediate integration and application as well as cost-effectiveness. More practical applications are sought in industry research. Examples of current research include enhancing a quick change of trailers to make it more efficient for drivers to swap trailers and keep moving; anti-idling technology; and the VII, which may have security implications and applications.

Any safety improvements will require joint development by the federal government, user, buyer, and even the competition. The focus of heavy-truck research must be on integration (integrating the various components developed through research), cost-effectiveness (to reduce the cost of vehicle ownership), reliability, and crash avoidance (Sharma).

Future Scenario

- Heavy-truck platooning.
- Goods distribution changes to a hub system.
- Georeferencing capabilities to notify dispatchers of the truck's location and route.
- Integrated control systems for managing truck components that lead to autonomous or partially autonomous driving.
- Alternative methods for moving freight and goods.

Research Needs

Margaret Sullivan

Focus on applied development to capitalize on technologies that are emerging in automotive, aerospace, and other research.

Richard Beyer

- Flexible, upgradeable systems that can be managed by the original equipment manufacturer and the supplier.
- Methods for ensuring that new electronic systems and components are cost-effective.

V. K. Sharma

- Liability issues associated with new technologies, especially those that assist or take control from the driver.

- Safety system enhancements that are cost-effective and increase productivity.
- Field operational tests that include a focus on customer benefits.
- Generation II telematics: automated pretrip inspection, driver behavior monitoring, integrating systems to minimize driver distraction, remote vehicle shutdown, route tracking, black box event recorder, biometric and smartcard ID, trailer prognostics, and road sensing, for example, of rising temperatures.
- Future top five list:
  - –Braking and vehicle stability,
  - –Driver fatigue and distraction,
  - –Intelligent safety belt technologies,
  - –Standardization and integration of safety systems, and
  - –Integration of safety systems with telematics.

Timothy Morscheck (Vehicle Collision Warning Systems)

Motor vehicle accidents are the cause of 10 million crashes per year in the United States; nearly 43,000 people die and almost 3 million are injured, many of them severely. The cost (in 2000 dollars) is more than $230 billion per year. Collision warning systems can help prevent crashes by

- Warning of impending collisions with objects and other vehicles,
- Improving driver sight distance and awareness of objects around the vehicle,
- Warning distracted or drowsy drivers, and
- Warning of unintended lane departures.

Some studies of collision warning systems have shown a reduction in overall accident rates, the cost recovery and payback for fleets is less than one year, and legal expenses can be reduced through accident reconstruction capabilities. Additional high-value functionality of CWSs can be gained by using adaptive cruise control, driver behavior monitoring, vehicle information monitoring, and automated reporting through wireless data transfer that enables exception reporting and real-time intervention by a fleet manager.

Audience Discussion

The following key points and questions were raised:

- All phases of the trucking industry are locked into a commodity market. Everyone at every level is struggling with cost constraints. The dilemma is not about future research; it is about how to get already available technology on the trucks and good drivers in the seats (Clarke).
- In Australia the chain of responsibility includes shipping, receiving, and the trucking industry. This has served to increase compliance with regulations and has other obvious advantages as well (audience).
- The challenge is to model crash factors and derive the few solutions that would make the most difference in reducing crashes (Belzer).
- Technologies, such as vehicle onboard radar, should be linked to public health issues to encourage customer demand from the general public (Husting).
- When the impact of technologies is tested, how is speed factored in? With increasing speeds on the part of all drivers, it seems that speed has a significant impact on how well the technologies work (McCartt).

VEHICLE DESIGN AND TECHNOLOGY: PRESENTATION

Utilizing Future Vehicle Technology to Improve Safety

D. M. Freund, S. J. Shaffer, L. W. Loy, and L. W. Minor

Over a 5- to 20-year horizon, CMV design will continue to evolve incrementally. Although those CMVs will appear to a casual observer to be similar to today's vehicles, they will bear much less resemblance to their forebears. CMV brakes will be lighter and more durable and will require less routine maintenance. CMV tires will be more durable and will be able to better maintain their set target pressures. Research is needed to improve the fundamental design of these components and to simplify and reduce the cost and complexity of communicating useful information from the sensors to the human user. Some CMVs will be equipped with aerodynamic accessories to adjust airflow around the vehicle: their fuel economy will be improved and, when needed, turbulence will increase to reduce stopping distance. Additional research is needed to optimize the design and placement of these devices and to improve their durability and compatibility with existing CMV design, since retrofit applications will be popular. The complexity of electronically controlled engines and drivetrains, brakes, tire pressure management, and driving environment management systems (such as lane keeping and headway management) will likely tax the abilities and availability of skilled technicians. Research is needed to develop methods for rapidly and accurately diagnosing electronic and mechanical malfunctions, for mistakeproofing maintenance and repair procedures, and for confirming the safe status of these technologically advanced CMVs. However, significant issues, such as privacy, must be researched to take full advantage of future onboard diagnostic technologies.

As the first author is writing this paper, she is looking at three scale-model trucks in her collection: a 1926 tank truck, an early-1950s truck tractor and matching trailer, and a mid-1990s vintage sleeper-berth tractor and trailer. The hypothetical time traveler would easily recognize all of these as trucks. They all have wheels, a compartment for the driver that is separate from the compartment for the cargo, a means for the operator to control the direction of the vehicle (i.e., a steering wheel), brakes for stopping the vehicle, and headlamps to light the road ahead.

If one takes a closer look at the wheels and tires, the picture begins to change. Under the hood are striking differences reflecting the type of engine (gasoline- or diesel-fueled) and the ratio of mechanical to electrical components. Driver–vehicle interaction was relatively limited, consisting of reacting to changes rather than being able to anticipate them.

As in the past 60 years, CMV design will continue to evolve incrementally over the next 5- to 20-year horizon. As with the comparison of vintage with contemporary vehicles, the CMVs of the near future will probably look very similar to today's vehicles. However, they will have much less resemblance under the hood to their forebears, and many of those new technologies will serve to improve the safety of the driver and the traveling public.

In this paper, a number of factors that influence the design and operation of CMVs are explored. Although the focus is on freight-transporting vehicles, many of the issues discussed apply to passenger-carrying vehicles as well. Because CMVs are designed to serve the needs of commerce, a discussion of vehicle configuration, weights, and dimensions comes first. Next the major vehicular systems are discussed: brakes, tires, and engine and powertrain. The safety of the driver, from the standpoint of both driver protection and safety-enhancing technologies, is explored next, and finally, the connection between CMV maintenance and operational integrity will be examined.

CMV Configurations, Weights, and Dimensions

CMVs exist to serve the needs of commerce, so they must operate efficiently. At the same time, they must function safely to protect the driver, the cargo, and the ability of the CMV to interact with other vehicles on the highway. CMVs of the future must maximize freight-carrying capacity while maintaining and preferably improving their stability and controllability (FHWA 1977).

The relationship between the configuration, weights, and dimensions of CMVs and the highway environment has been a dynamic one. The first freight CMVs were single-unit vehicles. Separating the power unit from the cargo compartment was a significant step to improving operational productivity. However, the roads of the early part of the 20th century were no match for the vehicle loads imposed by the burgeoning highway freight transportation industry, and 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) (FHWA 1977).

In May 1942 the Public Roads Administration (predecessor to the Bureau of Public Roads, later FHWA) and the American Association of State Highway Officials (predecessor to the American Association of State Highway and Transportation Officials) 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 (FHWA 1977).

Over the years, federal regulations on CMV vehicle weights and dimensions changed several times. In 1956 the federal gross vehicle weight limit was set at 73,280 lb (33,269.12 kg). In 1974 it was raised to 80,000 lb (36,320 kg). The 1982 Surface Transportation Assistance Act abolished vehicle length limits on the national network. The Intermodal Surface Transportation Efficiency Act (ISTEA) froze the weights of truck tractors 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. It also froze the maximum length of those cargo-carrying units operating on the national network (Interstate and other designated highways) (FHWA 2004).

Although the tractor–semitrailer combination vehicle is still the mainstay of the over-the-road fleet, combinations with two and three trailers (the latter where allowed under state laws and regulations) are in common use by less-than-truckload and some private motor carriers. Weights and dimensions of CMVs must adhere to federal requirements set to ensure that the structural capacity of bridges is not exceeded. There is no federal vehicle height restriction for CMVs; states' limits generally range from 13 ft 6 in. (4.113 m) to 14 ft (4.27 m) (FHWA 2004).

For CMVs hauling high-density freight, a reduced vehicle tare weight can offer direct improvements in operational efficiency. A motor carrier using state-of-the-practice aluminum wheels and wide-based single tires estimated in a January 2005 industry magazine that the company's vehicles enjoyed a savings of 165 lb (74.91 kg) per wheel, or 1,650 lb (749.1 kg) for a tractor-trailer combination vehicle, as well as a fuel saving of 2% to 3% (Lang 2005a). Additional research is needed to develop materials and CMV tractor and trailer fabrication methods to reduce the tare weight of the vehicle while maintaining or preferably improving their structural strength, stability, and crashworthiness.

The issue of CMV weights and dimensions is complex and contentious and will not be further addressed here. Any potential revisions to those limits would require upgrades for the braking and stability control systems, materials, and many components to ensure continued safe CMV performance.

Brakes

Bringing a 40-ton (36.28-mg) CMV to a safe and controlled stop is an absolute safety requirement. However, brake system defects and deficiencies are still the major causes for CMVs to fail a roadside inspection. There is a pressing need for technological innovation to improve brake reliability and maintainability.

CMV brakes have evolved incrementally since the 1920s in response to the increasing demands for stopping power, reduced vehicle tare weight, structural durability, and longer maintenance intervals. The first federal regulations for CMVs were published in 1936 and included a 20 mph stopping distance test. They were revised in 1939 to require that all brakes be operable at all times. Further revisions to the regulations, published in 1952 through 1971, addressed a requirement for brakes on all wheels, the provision of breakaway and emergency brakes, a revised stopping-distance requirement, and incorporation by reference to NHTSA Federal

Motor Vehicle Safety Standards 105 and 121. The requirement for front-wheel brakes for trucks and truck tractors with three or more axles went into effect for those vehicles manufactured starting July 24, 1980. The basic requirement for a 14-ft/s^2 deceleration rate was set in 1937 and remains in effect today (Shaffer and Radlinski 2004).

Two major revisions to CMV brake requirements came about in the 1990s. In October 1992, NHTSA issued a final rule requiring automatic brake adjusters (ABAs) on vehicles equipped with hydraulic brake systems and ABAs and brake adjustment indicators on vehicles equipped with air brakes with external adjustment mechanisms. In March 1995, NHTSA issued a final rule amending FMVSSs 105 and 121 to require antilock brake systems (ABS) to improve the lateral stability and steering control of these vehicles during braking. FMCSA issued in-use requirements for ABA-equipped CMVs in September 1995 and for ABS-equipped CMVs in May 1998 (49 CFR 393).

Except for highly specialized applications, S-cam brakes have essentially replaced wedge brakes. Air disc brakes are seeing an increasing share of the heavy-duty CMV market, especially on straight trucks. Many of today's CMVs use a combination of disc brakes on some wheels and S-cam brakes on others to optimize safety improvements from reduced stopping distance with a minimal increase in purchase cost.

The state-of-the-practice for onboard devices providing real-time measurements of brake performance has focused on brake stroke (generally mechanical switches or Hall-effect sensors), brake force (strain-gauged anchor pins and wheel-slip sensors), system air pressure, vehicle deceleration, and brake temperature. A recent study comparing various types of brake sensors found that the strain-gauged anchor pins showed a highly predictable relationship between force data and vehicle acceleration rate. They could also differentiate between an out-of-adjustment brake and one with an oil-soaked lining. Stroke sensors and wheel-speed sensors were also able to provide indications of brake location-specific deficiencies but to a somewhat lower degree of resolution (Kreeb et al. 2003a). Research is needed on brake force sensors to demonstrate their long-term reliability and potential use in CMV brake systems. Research is also needed to develop improved methods of measuring wear on disc brakes.

Over the next several years, the trends toward incremental improvement of mechanical CMV brakes will continue and probably accelerate. Foundation brakes will be lighter and more durable and require less routine maintenance. Many of these changes will be driven by operational experience, but others will emerge as designers capitalize on advancements in digital modeling software and economical, cutting-edge desktop computers. Designs are being optimized to increase the strength of the portions of components subject to particular stress concentrations and to provide cooling to areas particularly subject to heat buildup. New steel alloys and nonmetallic materials are likely to see increased use.

Brake systems will incorporate a wide range of onboard sensors to monitor brake performance. They will provide drivers with an early warning of changes from optimal performance levels, and they may compensate for some deficiencies without the driver's intervention. New types of sensors, perhaps including a combination of brake force, brake piston stroke, and wheel speed, can provide a comprehensive detailed picture of how each brake is operating. If a recording system is used, this same information can be made available to maintenance mechanics. Many CMVs will be equipped with sensors that can provide wheel-by-wheel readouts during a pretrip inspection, allowing a single person, such as a driver or mechanic, to perform an inspection. Research is needed to define the key parameters to be monitored and displayed. Research will also be needed to determine the appropriate degree of performance decrement at which to notify the driver and perhaps the level at which the vehicle will not allow itself to be driven until definitive action, such as adjustment, repair, or replacement, is taken.

In the next several years, electronically controlled brakes of varying sophistication levels will enter the marketplace and provide an enhanced platform for integrated vehicle stability-control systems. The first systems are likely to be overlays to the dual-pneumatic (2P) systems required under FMVSS 121. Later systems may be able to replace one of the pneumatic systems with an electronic "by wire" method to transmit the brake systems signals needed for both activation and performance monitoring. Research is needed to determine if a single or dual electronically controlled brake system (1E or 2E) would provide at least an equivalent level of safety as that of today's 2P systems. Research is also needed to enhance the robustness, accuracy, and reliability of these integrated systems, to determine optimal selection and placement of sensors, and to simplify and reduce the cost and complexity of communicating useful information from the sensors to the human user.

Tires

Although CMVs of the distant future might not have direct contact with a roadway surface, it is likely that the vehicles of the next 20 years will continue to roll on tires. Tire safety improvements through technology are needed to improve tire maintainability in operation, repair, and reuse. Tire pressure maintenance is probably the most critical tire safety–related need to ensure both the stability and controllability of the CMV and to prevent traffic incidents resulting from other vehicles' interaction with debris from failed tires.

CMV tires have gone through several evolutionary changes. When a single wheel on each end of an axle became insufficient to support the weight of a CMV, the cost-effective solution at that time was to add a second, "dual" tire. Beginning in the 1980s, tire manufacturers began to explore the notion of a single wide-base tire to take the place of duals. However, the early "super single" tires had a relatively small contact area to transmit the CMV's loading to the pavement and had the potential to increase pavement damage dramatically (Bonaquist et al. 1988). Newer wide-base single tire designs are believed to transfer loads through a larger contact area while still providing advantages of decreased rolling resistance and weight.

Tire manufacturers have also experimented with the formulation of tire carcass and tread compounds, ply and belt materials, and tread patterns to improve durability, heat resistance, fuel economy, and traction. After the replacement of solid with pneumatic (air-filled) tires in the early part of the 20th century, the most significant change in tires for all types of vehicles has been the introduction of radial tires.

Different tread patterns are available for use on tractor steer axles, drive axles, and trailers as well as for over-the-road, urban driving and vocational applications. As is the case with brakes, the availability of advanced design tools will likely provide opportunities for material and structural optimization. Research is needed to enhance the safety performance of tires by allowing them to provide more predictable traction levels on wet, slick, and dry roads so they perform as interactive components of the CMV's stability and control system. Perhaps active tread designs and active tires could be designed to respond to changes in highway surface condition to optimize traction. This would require research on materials, sensors, and control systems.

Tire-related costs are the largest CMV maintenance item for a motor carrier fleet. Tire pressure maintenance is time-consuming, taking perhaps 30 min per week for an 18-wheel tractor-trailer combination CMV. However, an underinflated tire has higher rolling resistance and decreases the vehicle's fuel economy. Its life is also shorter, thanks to sidewall flexing, which can lead to breaking of the wires making up the plies and to heat buildup. Improper tire inflation increases the cost of tire procurement by 10% to 13%, is responsible for about 0.6% decrease in fuel economy for a typical for-hire freight operation, and may be responsible for approximately one road call per year per tractor-trailer combination vehicle (Kreeb et al. 2003b).

Tire pressure management systems have been used in specialty CMV applications for more than 20 years. Their first applications were in CMVs used both on and off the road for construction and logging, where a lower tire pressure was needed to provide the larger contact area to keep the vehicles from bogging down. These systems needed to accommodate a large pressure range. Today's tire pressure monitoring (indicators) and tire pressure maintenance (adjustment of pressures to preset levels) systems are designed to operate on much narrower ranges. These systems are beginning to enjoy wider fleet applications. Additional research is needed to ensure the reliability of these systems over the working life of tractors and trailers and to simplify their maintenance requirements.

Most CMV tires are retreaded. According to the Tire Retread Information Bureau, of the nearly 33.8 million replacement tires purchased by fleets in 2000, more than 18.1 million were retreads. A tire carcass that has been properly maintained can be retreaded up to three, and possibly four, times. This provides significant cost savings over purchases of new tires and drastically decreases the demand for oil [a new tire requires 22 gal (83 L) of oil; a retread, 7 gal (26.5 L)] and the solid waste stream (Tire Retread Information Bureau 2005). At retreading time, it is difficult to assess the internal condition of tires reliably and rapidly. Research is needed to improve the durability of tire sidewalls and to develop techniques to improve the ability of a CMV maintainer and the retreader to diagnose rapidly internal tire damage that would prevent the tire from being safely and successfully retreaded.

If a tire experiences a catastrophic blowout or a structural failure, a driver has relatively few options other than riding it out. A skilled CMV driver with a power-steering-equipped vehicle can bring it to a safe stop even if a steer-axle tire fails. A failure of a tractor drive tire or a trailer tire can certainly affect the handling of a vehicle, but it presents somewhat less of an immediate hazard because the load is transferred to the other dual tire of the pair. However, if wide-based single tires are used, this redundancy is lost. Research is needed to develop cost-effective tire-self-preservation systems that will allow the CMV to be driven safely to a repair facility.

A reduction in CMV breakdowns due to tire failures will be an important target for research because of the large potential cost savings. Research is needed to improve tire durability and their ability to maintain air pressure settings. As with brakes, there will be a need to improve the accuracy, durability, and communications simplicity of tire pressure and condition sensors. Research is needed to enhance current methods of detecting tire failure using pressure, acoustic, or vibration signal monitoring. Research is also needed to integrate tire performance into the braking and stability control continuum to provide improved accommodation of the CMV to wheel- or tire-specific performance shortfall, perhaps through an ECBS feedback loop.

Although solid tires were used on some of the earliest trucks, the pneumatic rubber tire has clearly had a long history. However, new materials might present attractive options from both economic and safety standpoints.

Polyurethane is one potential material to consider for commercial truck tires of the future. Polyurethane is a fully reacted polymer, in which every molecule bonds with another so that it is chemically inert, which keeps it from oxidizing or leaching chemicals, theoretically extending tire life. With rubber, unbonded elements left over from the vulcanization process continue to react as the tire ages, leading to hardening, cracks, and more frequent trips to the tire store. The polyurethane tire manufacturing process consists of a simple spin-casting operation that can produce a new tire every 3 min.

Prototype polyurethane tires of the past ran into problems during real-world testing, such as poor wet traction and meltdown during braking. New polyurethane tire formulations have compared favorably in track tests with top-of-the-line run-flat rubber tires. In one key metric, rolling resistance, advanced polyurethane tires have shown results of up to 45% better than the competitive rubber test tires, potentially translating into a 10% increase in fuel economy (Whitfield 2005). Most of the polyurethane tire research has been in the automotive and light truck area. Research should be conducted to address the potential use of polyurethane tire technology for CMV applications, including interaction with CMV brake systems.

Polyurethane foam inserts have been used successfully in other vehicles in lieu of traditional air or nitrogen-inflated tubes. This could potentially eliminate tire pressure maintenance and monitoring concerns. However, given the heat-generating nature of CMV tires, research will need to focus upon the performance of these new materials.

Propulsion Systems, Fuels, and Aerodynamic Devices

For CMVs equipped with the next generations of propulsion systems and using the next generations of fuels, safety needs will be similar to those of today. The fundamental concerns will be ensuring that the vehicle can be fueled and repaired safely, ensuring that fuel delivery and engine emissions do not pose a safety hazard to the driver or to others, and designing crashworthiness features into the fuel storage and delivery systems.

A CMV of the future might have an engine fueled by diesel, a diesel-biofuel mixture, or a nonpetrochemical fuel. To meet fuel conservation and environmental regulations as well as motor carriers' high performance expectations, many of the CMVs of the future will likely have a hybrid powertrain and regenerative braking system. Over a longer time horizon, some CMVs may have hydrogen-based fuel systems. Regardless of the type of fuel used, there are numerous opportunities to improve the fuel economy of CMVs (Lovins et al. 2004). These include reduction in parasitic losses in the engine and drivetrain, provision of driver-assistive tools (including automated transmissions) to optimize gear selection, conversion of hydraulic components to electrical ones, and improvement in the energy efficiency of accessories, auxiliary loads, and aerodynamics to reduce drag.

One nonpropulsion area in which fuel economy will improve in the short term is through a reduction in engine idling. Auxiliary engines to power truck-mounted equipment and to provide cab and sleeper-berth heating and cooling are becoming increasingly popular. For some CMV users, shore power, off-board power, and communications systems offer additional alternatives. In most, if not all, of the CMVs of the future, engine idling will be virtually eliminated.

Research is needed to ensure that drivers using CMVs equipped with these new systems and technicians responsible for maintaining them are able to transfer safely and upgrade the skills acquired from working with conventional vehicles. This will be especially important for CMVs equipped with new and retrofitted auxiliary power units and the next generation of diesel engines.

Hybrid Vehicles

Hybrid vehicles are propelled by an electric motor and use a gearbox rather than a traditional transmission. Batteries provide electricity to an electric traction motor through the propulsion control system, and the traction motor drives the wheels. A conventionally fueled engine (gasoline or diesel) powers a generator that provides additional electricity through the propulsion control system to the traction motor and also recharges the batteries. The propulsion control system manages the flow of electricity to make the vehicle move as the driver commands and uses regenerative braking to slow the vehicle and simultaneously recharge the batteries.

Hybrids have smaller engines that run at a more consistent operating speed. The regenerative braking system removes some of the load from the foundation brakes and reduces the need for brake maintenance. Hybrids do not have a traditional transmission, a major maintenance item for vehicles used in urban areas. The reduced parasitic loads, utilization of the electric motor during a large part of the driving cycle, and the regenerative braking system combined can lead to up to 50% higher fuel efficiency than gasoline or diesel engines on comparative vehicles (U.S. Department of Energy 2001; Kilcarr 2005).

In the next 5 to 20 years, the significant fuel economy advantage of hybrid propulsion systems will lead them to become rapidly the CMV of choice in urban applications. For some of the early applications in lower-weight-class CMVs, "scaling up" the hybrid powertrains of early 21st century passenger cars will provide a reasonably simple entry path. Research is needed to optimize the complex feedback loop requirements to ensure safe acceleration and deceleration of these vehicles. In particular, research will be needed to develop robust sensors and redundant signal transmission pathways. Research is also needed to ensure that fueling systems and fuel storage compartments of hybrid and nonpetroleum-fueled CMVs are designed for safe operation and maintenance. This is particularly important for high-voltage components and systems. As noted earlier, research is needed to ensure that CMV drivers can successfully transfer and adapt their driving skills to these vehicles.

In the more distant future, but still within the 20-year horizon, some CMVs using hydrogen-derived fuels will enter the national fleet.

Research concerning the initial generations of hydrogen-fueled vehicles are already under consideration and development at the U.S. Department of Transportation and will not be further addressed in this paper.

The next generations of CMVs are likely to use hydrogen in the form of metal hydrides and other compounds in fuel cells. Research will be needed to develop hydrogen-based fuels (including hydrides) and fuel-storage media and delivery systems that are both crashworthy and safe to transport, store, and use.

Aerodynamic Devices

Although much past research on aerodynamic devices has centered on their potential to improve CMV fuel economy, they offer myriad possibilities for improving CMV safety, such as reducing splash and spray; improving visibility by diverting rain and snow from windshields, mirrors, and lamps; improving vehicle stability; and reducing stopping distance.

The fuel crisis of the 1970s generated considerable interest in improving the fuel efficiency of highway vehicles. Trucks and truck tractors were significant beneficiaries of research on the influence of aerodynamics. Cabs shaped with rounded corners, cab and truck-mounted air deflectors, and cab body fairings and side extenders helped to generate improvements in coefficient of drag from approximately 1.0 to 0.6 to 0.7 and improvements of more than 50% in average fuel economy from a 1970s baseline of 4 mpg. Trailers were the subject of considerable laboratory research, and drag-reduction tools such as trailer side skirts and boat-tails were developed, but fewer of those findings have been translated into commercial products. In the face of swiftly rising fuel prices, there is renewed interest in these devices as well as next-generation tools for tractors and trailers. These include gap seals placed between the rear of the tractor and the trailer and dynamic airflow devices (Cooper 2003; Englar 2003).

Additional improvements in aerodynamics are certainly possible, provided that roughly 20% of the fuel use of a Class 8 combination vehicle goes into aerodynamic losses. The CMVs of the future will use aerodynamic accessories that can do double or even triple duty. These devices will be able to both smooth the airflow around the vehicle to improve fuel economy and increase turbulence when needed to reduce the vehicle's stopping distance.

Advances in materials could allow production of energy-absorbing skirts and low-height fairings that could also provide protection against side underrun and frontal crashes.

Research will be needed to optimize the design and placement of aerodynamic devices to take full advantage of the nature of smooth and turbulent airflows around CMVs and achieve these mutually beneficial outcomes. Research will also be needed to improve both their durability and refitting for both tractors and trailers and to demonstrate their cost-effectiveness.

Driver–Vehicle Interaction

Although our time traveler could probably ascertain without much difficulty the procedures necessary to power up and drive the 1920s, 1950s, and 1990s CMVs, the driving experience would be quite different in each. The sheer physical strength required to control the two older vehicles would have been substantial, since neither was equipped with power-assist steering and the suspensions were of a coil-spring or leaf-spring type. By the time the road-weary driver had the opportunity to sample the early-1990s CMV with its air-ride suspension, vibration-damping engine mounts, and power-assisted steering, he or she might have believed that things could not get even better. For real-world drivers, things will continue to improve.

There are several continuing research challenges for the CMVs of the future: to provide a driving environment that provides a comfortable, alertness-enhancing, and crashworthy workspace; to promote the driver's efficient and effective management of driving task elements through improved design of displays and controls; to improve the driver's situational awareness of events inside and outside the CMV without causing cognitive overload; and to address the potential for autonomous control if the driver becomes unable to control the CMV.

Driver Workspace

The most visible change in the driver's workspace occurred as a result of changes to federal weight and dimension regulations. When an overall CMV length limit was implemented in 1956, the need to conserve cargo-carrying capacity led to a need to reduce the length of the power unit. The CMV manufacturers responded to this need by offering cab-over-engine tractors. Research performed in the early 1970s found that the effects of a hot environment and vibration stress adversely affected drivers' stress levels, subjective fatigue, and driving performance (Mackie et al. 1974).

As noted earlier, the 1982 Surface Transportation Assistance Act abolished vehicle length limits on the national network. The response, starting in the mid-1980s through the 1990s, was a return to the conventional cab-behind-engine configuration for over-the-road tractors. Cab-over-engine and cab-ahead-of-engine tractors and trucks are still used in many urban applications because they are more maneuverable and offer better visibility. This configuration has a positive influence on driver comfort by moving the heat, noise, and vibration of the engine further away from the driver.

Unfortunately, the longer hoods of these vehicles also made it more difficult for drivers to see objects ahead of their vehicles. Several tractor manufacturers conducted research in the mid-1990s that led to the sloped hoods now in common use. These not only improved drivers' forward vision by aligning the hood at an angle corresponding with their line of sight but also provided an added bonus of improved aerodynamics.

Automated transmissions considerably simplify the task of driving a CMV. Unlike the automatic transmissions used in automobiles and light trucks, these transmissions must still be shifted, but they are synchronized with the engine and do not require use of the clutch pedal except when the engine is started. Therefore, they eliminate an activity that can be both physically and cognitively challenging.

Use of power-assisted steering greatly reduced the sheer muscle power required for CMV drivers to safely guide their vehicles. One product introduced in the late 1990s uses a force-feedback system to further enhance steering during low-speed maneuvers and highway speeds, where it acts against the forces induced by crosswinds (Lang 2005b).

Because truck manufacturers have recognized that drivers come in a large range of heights and girths, significant improvements in driver-workstation ergonomics have occurred (Kinghorn and Bittner 1993). All over-the-road trucks, and many other CMVs, have air-suspended driver's seats that provide a significant range in height adjustment and vibration isolation from the vehicle's suspension. Adjustable steering columns improve the driver's ability to place the steering wheel at a comfortable height and tilt angle.

The CMVs of the future will provide a higher degree of customization of the workspace to fit the driver's height, size, and reach. The clutch pedal will be gone. Seats will conform to the driver's preferred fit and will promote optimal driving posture. However, additional anthropometric research will be needed to update the studies of the 1980s and 1990s to account for long-term trends of increasing stature, changes in the ethnic and gender composition of the workforce, data errors, and lack of comprehensiveness of the prior studies. Research will also be needed to enhance alertness-promoting properties of the physical environment, such as postural support, temperature of air and contact surfaces, improved lighting, and reduced glare.

Driver Assistive Systems

The clear trend in the availability and use of driver assistive systems has been to change the driver's role from that of a monitor or a victim of the vehicle and highway environment to that of an active participant in crash prevention. This role is especially important in situations where the CMV driver must respond to the actions of drivers of other vehicles.

Innovations in recent years have included new mirror designs that address blind spots in front of, behind, and along the sides of CMVs (the "No Zones"). Object incursion detection systems use radar, sonar, and infrared spectra to note the presence of vehicles, pedestrians, and fixed objects. In the near future, new devices will further enhance the ability of drivers to see around their CMVs. These devices, many of which are new to the marketplace in the last several years, include cameras, improved lighting (including lighting that operates on wavelengths outside the visible spectrum), and adaptive headlamps that "see around" curves.

Other systems enhance the driver's awareness of his or her interaction with the driving environment and improve the driver's ability to make proactive adjustments in the vehicle's speed and placement. For example, adaptive cruise control, currently available as an option on some Class 8 CMVs, assists the driver by monitoring and maintaining a safe headway to the vehicle immediately ahead. These systems are designed to take limited control of the CMV. If a driver does not take action and a collision is computed to be imminent, the systems interact with the CMV engine, transmission, and engine brake—sometimes in combination—to slow the vehicle to prevent a crash. Some systems also monitor the adjoining lanes for potential incursions when the CMV driver is preparing to change lanes.

More recently, devices have been introduced that monitor the tracking of vehicles within the boundaries of a traffic lane, which is a driving performance gold standard when it comes to driver alertness. Other driving performance monitors, such as steering wheel sensors, are being tested and evaluated. The next generation of systems, still on the drawing board, may actively take control of CMV steering controls to prevent the vehicle from leaving the driving lane unless the driver is signaling an intention to cross.

Another family of driver alertness monitoring devices takes the approach of monitoring driver physiological changes, such as eyelid closure, head nod and droop, and fidgeting. These devices have been the subject of intensive research by the U.S. Department of Transportation and other agencies and organizations, but the results are only now beginning to enter the marketplace. The CMVs of the future may well include multiple driver alertness and performance monitoring systems to provide a more comprehensive and precise assessment and to provide earlier, more usable feedback to the driver (Dinges 1997).

For all of these systems, research is needed to improve their design (including sensor selection and signal processing and communication), reliability, consistency of performance, and appropriate use in driver self-assessment or motor carrier oversight. This research should address a broad set of criteria from the scientific–engineering, practical–implementation, and legal–policy perspectives. Research is also needed to develop effective methods to train or retrain drivers who have never used the devices before or who are accustomed to conventional devices, such as mirrors, to use them safely. For any device that could transfer control from a driver, such as full active control of steering or foundation brakes, research is critically needed to predict and, it is hoped, prevent introduction of risk homeostasis.

Driver Protection

Protecting a driver from the effects of crash forces involves restraining the driver's movement to prevent impact with the CMV interior and ejection from it and presenting surfaces that deform (such as an airbag) or break away (such as a collapsible steering column) on impact.

The drivers of the 1920s- and 1950s-era CMVs enjoyed crash protection that was basically comparable with that for drivers in smaller vehicles—none other than that provided by the mass and crush characteristics of the truck or tractor cab. Limited comprehensive crash data were available until the 1970s, but what data were available indicated an alarming trend—a 50% increase in truck occupant fatalities between 1975 and 1979 (Krall 1993). Although many CMV safety requirements had been part of federal regulations since the 1950s (including the original requirement for rear-underride guards and sleeper berth egress), comprehensive vehicle regulations that addressed CMV driver protection did not come about until the 1970s, similar to the time frame for passenger car driver safety. The initial seat belt requirements for trucks and truck tractors used in interstate commerce required that by June 30, 1972, those vehicles manufactured on and after January 1, 1965, be equipped with seat belt assemblies required by NHTSA regulations at their date of manufacture. Today, although FMVSS 208 allows either Type 2 (lap plus torso) or Type 1 (lap only) seat belts, all U.S. truck manufacturers have provided Type 2 belts as standard equipment since the 1980s. The reduction in truck occupant fatalities of over 50% between 1980 and 1992 is largely attributed to seat belt use (Krall 2002).

Passenger and occupant restraints in CMVs of the future could well be passive devices that fit themselves to the driver, seated passenger, and sleeper berth occupant. However, this one area cannot await for the future. A 2003 observational study in 12 states showed a set belt usage rate of 48% among CMV drivers. In contrast, passenger cars and sport utility vehicles showed 81% and 83% seat belt use, respectively (Knoblauch et al. 2003). Additional research is needed immediately to determine the reasons for low occupant restraint use among CMV drivers and to develop effective means of increasing their use. These strategies could range from making them easier to attach and more comfortable to wear to developing interlocks that would prevent a CMV from being driven unless the driver, and also passenger or sleeper berth occupant, were properly restrained.

Because of the wide variations in cab configuration, it has been difficult to define a crash cell and design driver protection devices. There is a continuing need for research to improve the driver compartment crashworthiness of CMVs.

The truck of the future must also continue to provide protection to the occupant of the sleeper berth, whether the CMV is moving or stationary. The federal motor carrier safety regulations require a "ready means of exit from a sleeper berth into the driver's seat or compartment" (49 CFR 393), and FMVSS 302 sets flammability standards that apply to sleepers (49 CFR 571.302).

Research is needed to ensure that changes to the materials and structural designs of CMVs, including their cabs and sleeper berths, provide protection to the driver and other occupants in the event of collision, rollover, submersion, and fire.

Crash Mitigation: Vehicle Aggressivity

The physical interrelationships between CMVs and other vehicles in crashes have generally been taken as a given. The vehicle with the larger mass always brings more energy to a crash, and the smaller vehicle is invariably at a severe disadvantage. NHTSA's research in the 1990s began to explore methods of reducing this aggressivity via modifications to the CMV, enabling it to absorb some of the crash energy (NHTSA 2000). In the decade since that work was performed, computing power and numerical modeling techniques have made significant advances.

The automotive and aerospace industries have generated new types of materials and fabrication techniques to improve strength while allowing energy to be absorbed. In the future, CMVs will commonly incorporate energy-absorbing materials and design in their construction. This can reduce the impact energy in crashes, significantly decreasing damage and loss of cargo and injuries or fatalities to CMV drivers, bus passengers, and occupants of other vehicles.

One potential class of materials is hyperelastics, such as specially formulated polyurethanes. They have been shown to reduce the force in forward impacts by as much as 65% at 50 mph in tests and modeling studies of crash barriers for racing cars (U.S. Patent Application 10/991,080). These hyperelastic polyurethane materials may also be used to replace current truck underride guards. The energy absorption of these materials could reduce the severity of impact for cars and trucks striking the rear of trailers and trucks and could reduce the amount of damage to trailers: underride guards compliant with FMVSS 223 tend to translate the force of the impact into the rear structure of the trailer, damaging the structural integrity of the trailer beyond repair.

Hyperelastic polyurethanes and other types of nonmetallic materials bring several other potential advantages to CMVs. They reduce weight and improve long-term appearance, simple repair, and resistance to road salts and deicing chemicals.

Research is required to optimize and transfer impact energy–absorbing technology from infrastructure devices to vehicles. Additional research will be needed to optimize the use of these and other types of advanced materials in CMVs, to develop efficient and cost-effective manufacturing methods, and to demonstrate long-term benefits.

MAINTENANCE

Well-trained mechanics and technicians will be needed to service complex 21st century CMVs. The complexity of electronically controlled engines and drivetrains, brakes, tire pressure management, and driving-environment management systems (such as lane-keeping and headway management) will likely tax the abilities and availability of skilled technicians. The mechanic of the future will likely need a strong set of skills in electronics and computer systems diagnosis and maintenance. Although the return of U.S. military veterans, most with strong advanced electronic skills, may somewhat ease the shortage of qualified technicians, the need for self-diagnosing CMV systems will continue to be strong.

The inspector, mechanic, or both will use wireless scan tools to determine the health of a wide variety of systems and their individual components. Sensors will be miniaturized and will transmit data to the high-speed data CMV (J1939, ISO, or their successors) and they will also contain the manufacturer's original specifications and settings to provide performance baselines.

Research is needed to develop the sensor firmware and diagnostic software for rapidly and accurately diagnosing both electronic and mechanical malfunctions and for mistakeproofing maintenance and repair procedures. Carrier safety managers, roadside enforcement personnel, and safety compliance officers need a method to confirm the safe status of these technologically advanced CMVs, both in a prescreening mode (CMV traveling at or near highway speed) and when the CMV is stationary. However, significant issues, including privacy, must be researched to take full advantage of future onboard diagnostic technologies.

REFERENCES

Bonaquist, R., C. Churilla, and D. Freund. 1988. Effect of Load, Tire Pressure, and Tire Type on the Response of a Flexible Pavement. In *Transportation Research Record No. 1207*, TRB, National Research Council, Washington, D.C., pp. 207–216.

Cooper, K. R. 2003. *Truck Aerodynamics Reborn—Lessons from the Past*. SAE Technical Paper 2003-01-3376. Society of Automotive Engineers, Warrendale, Pa.

Dinges, D. F. 1997. The Promise and Challenges of Technologies for Monitoring Operator Vigilance. *Proc., Managing Fatigue in Transportation International Conference*, American Trucking Associations, Alexandria, Va.

Englar, R. J. 2003. *Drag Reduction, Safety Enhancement, and Performance Improvement for Heavy Vehicles and SUVs Using Advanced Pneumatic Aerodynamic Technology*. SAE Technical Paper 2003-01-3378. Society of Automotive Engineers, Warrendale, Pa.

FHWA. 1977. *America's Highways 1776–1976: A History of the Federal Aid Program*. U.S. Department of Transportation.

FHWA. 2004. *Federal Size Regulations for Commercial Motor Vehicles*. Pub. FHWA-HOP-04-022. U.S. Department of Transportation.

Kilcarr, S. 2005. Measuring Hybrid Truck Potential. *Fleet Owner*. Jan. 11. http://fleetowner.com/news/hybrid_truck_011105.

Kinghorn, R. A., and A. C. Bittner, Jr. 1993. Truck Driver Anthropometric Data: Estimating the Current Population. *Proc., Human Factors and Ergonomics Society 37th Annual Meeting*, Seattle, Washington.

Knoblauch, R. L., et al. 2003. *Safety Belt Usage by Commercial Motor Vehicle Drivers*. http://www.fmcsa.dot.gov/safetybelt/fmcsafinal_safetybeltstudy_Nov2003.htm.

Krall, F. L. 1993. *The Decade of Declining Heavy Truck Fatalities: A Tribute to the Cooperative Process*. SAE Technical Paper 933058. Society of Automotive Engineers, Warrendale, Pa.

Krall, F. 2002. Legislative Impact on the Design and Operational Safety of Large Trucks in the United States. *Proc., International Truck and Bus Safety Research and Policy Symposium*, Knoxville, Tenn.

Kreeb, R. M., B. T. Nicosia, and P. J. Fisher. 2003a. *Commercial Vehicle Tire Condition Sensors*. Report FMCSA-MC-PSV-04-002. FMCSA, U.S. Department of Transportation.

Kreeb, R. M., B. T. Nicosia, D. Skorupski, and R. Radlinski. 2003b. *On-Board Sensors for Determining Brake System Performance*. Report FMCSA-MC-PSV-04-001. FMCSA, U.S. Department of Transportation.

Lang, D. 2005a. Carriers Seek Lighter Vehicles, Heavier Loads. *Transport Topics*, Jan. 31, pp. 1 and 8.

Lang, D. 2005b. Trailblazing Designer Has Been Down This Road Before. *Transport Topics*, July 19. http://www.ttnews.com/members/printEdition/0002132.html. Accessed December 2005.

Lovins, A. B., E. K. Datta, O. Bustnes, J. G. Koomey, and N. J. Glasgow. 2004. Winning the Oil Endgame: Innovation for Profits, Jobs, and Security. Rocky Mountain Institute, Snowmass, Colo. www.oilendgame.com.

Mackie, R. R., J. F. O'Hanlon, and M. McCauley. 1974. *A Study of Heat, Noise, and Vibration in Relation to Driver Performance and Physiological Status*. Publication DOT-HS-801-315. U.S. Department of Transportation.

NHTSA. *Heavy Vehicle Aggressivity Program*. July 2000. http://www.nrd.nhtsa.gov/departments/nrd-01/summaries/havp_02.html. Accessed March 2, 2005.

Shaffer, S. J., and R. Radlinski. 2004. *Braking Capability Requirements for In-Use Commercial Vehicles—A Chronology*. SAE Paper 2003-01-3397. Society of Automotive Engineers, Warrendale, Pa., October.

Tire Retread Information Bureau. 2005. www.retread.com.

U.S. Department of Energy. 2001. *Diesel Hybrid Electric Buses*. Field Operations Program, Office of Technology Utilization. www.avt.nrel.gov/pdfs/nyc_bus.pdf.

Whitfield, K. 2005. Tires of the Future? *Automotive Design & Production,* February. www.autofieldguide.com/articles/020508.html.

Roadway Design and Operations

John Pearson, *Council of Deputy Ministers Responsible for Transportation and Highway Safety, Canada, Provocateur*
Douglas Harwood, *Midwest Research Institute*
Dan Middleton, *Texas Transportation Institute*
Edward Fekpe, *Battelle Memorial Institute*
Gerald Donaldson, *Advocates for Highway Safety*
Jeffrey Short, *American Transportation Research Institute*
Alan Clayton, *University of Manitoba, Moderator*

There is not enough money in the Highway Trust Fund (HTF) to maintain the roads adequately. Decisions about funding sources and allocation of funds need to explore alternative methods for paying road maintenance and construction costs.

The HTF is a major source of funding for highway infrastructure projects and maintenance. Revenues are drawn from various excise taxes and also a heavy-vehicle use tax. Passenger vehicles also pay into the fund. The portion paid by trucks is about 42%. The HTF is not increasing in revenues because the fuel tax has remained stationary since 1993 and vehicles are more fuel efficient. Prices may fluctuate and inflation has its effect, but the amount of fuel purchased and the fuel tax remain essentially unchanged. In addition, HTF funds are used for programs beyond highway maintenance and construction, such as transit, air quality, and research; therefore, the states must also generate revenue for highway funding. That situation leads in some cases to tolls on highways and Interstates.

As has been said before, the trucking industry is ultracompetitive. Profit margins are low, and this state of affairs is complicated by competition among other freight modes, economic recessions, driver shortages, insurance rates, and the volatility of fuel costs.

Key questions are the following:

- Are customers willing to pay for toll surcharges as much as they are willing to pay for fuel surcharges because they are aware that there has been an increase in the cost of fuel?
- Are secondary and parallel roads designed for truck traffic?
- If trucks divert to rural and local routes to avert toll charges, is there an effect on safety?
- How should the revenue from the HTF be allocated? What are the cost benefits of the various allocations?
- Are there alternative revenue sources that can be explored?
- How can we ensure that everyone who uses the roads pays a fair share?
- Should passenger vehicles be taxed as trucks are now?
- Should the fuel tax be tied to inflation or should it just be a flat rate such as 24.4 cents per gallon? Should the fuel tax increase or decrease as prices change? Should it be a percentage?
- Are the funding formulas equitable for all highway users?
- How can tolls be addressed in an equitable and necessary fashion?
- What is the relationship between congestion and safety?

Panel Discussion

Doug Harwood, Dan Middleton, Edward Fekpe, and Gerald Donaldson; John Pearson, provocateur

Background

Gerald Donaldson

Building the Interstate system diverted resources from other local and secondary road systems. By the early 1970s capacity demand had increased but the states, for the most part, did not upgrade their road systems to Interstate standards. Truck weights were allowed to increase in the 1970s, and in the 1980s public policy opened highway miles to doubles even though many roads were not capable of handling the large, heavy trucks.

Increased congestion has caused states to open even more local roads to trucks. The infrastructure for supporting the number and weight of trucks is radically underfunded. Except for minimal standards and control, decision making is at the state level and the standards among states vary widely.

Future Scenario

- Increased number of and more powerful trucks,
- Higher ratio of trucks to private vehicles,
- Increased technology use,
- Evolving technologies (design and operations),
- Increased congestion resulting in capacity problems,
- Aging infrastructure,
- Limited funding,
- New truck configurations:
  - Productive and efficient?
  - Infrastructure-friendly?
  - Safety-sensitive?
- Aging fleet with dated technology on trucks,
- Trucks separated from other vehicles,
- Roads upgraded to Interstate standards,
- Limited controls on truck operations in congested urban areas,
- Diversion of freight to rail and other modes,
- Alternative funding sources,
- Changes in vehicle design,
- Changes in handling and control properties,
- More safety features on trucks, and
- E-commerce increasing with potential effects such as
  - Warehousing needs,
  - Increased smaller delivery trucks in urban areas, and
  - Modified traffic patterns.

Roadway Design

Douglas Harwood

Trucks and buses run on the roads, and roads are an important part of the safety equation. The basic geometric design criteria are set by the AASHTO Green Book, which states national policy on geometric design, and many states have their own design manuals, most of which are modeled in one way or another on the Green Book.

Ezra Hauer has initiated a dialogue about the difference between nominal safety and substantive safety. The Green Book or any fixed design policy of that type represents nominal safety. It is based on years of experience in designing highways. The experience produces a sense that certain designs will operate safely and well in terms of service. Hauer has encouraged a move toward substantive safety, that is, knowing with specific design features how the highway is likely to perform from a safety point of view. This could lead in the future to performance-based design criteria. Rather than rely on the Green Book, engineers would focus on performance in terms of levels of safety and levels of service for traffic operations.

Performance-based design criteria for roads are a challenge because the relationships between geometric design and safety are not completely understood. It is possible under the current state of the art that performance-based design criteria could be developed for the rural two-lane highway, which seems to be where most of the safety knowledge has been catalogued, but new knowledge for other highway types is being developed in a number of ongoing research efforts, including the effort by TRB and NCHRP to develop a highway safety manual. This manual is viewed as equivalent to the TRB Highway Capacity Manual, which is used to analyze traffic operations on the road. The new manual would be useful for predicting levels of safety on roads and predicting the benefits in safety that would result from redesign of roads.

Most of the safety knowledge is from studies that consider the effects on safety of the mixed traffic stream. It is not specific to trucks, but in many cases it is indicative. One of the areas in which we have less knowledge than we need relates to combinations of roadway geometric elements. In geometric design, policies largely treat one design element at a time and fairly independently. The interactions between those geometric elements are poorly understood.

The lowest crash rates on our roadway systems are on limited-access highways, for example, freeways and toll roads. Higher crash rates occur on multilane nonfreeways where direct access is permitted, including both multilane divided highways and multilane undivided highways. Two-lane highways have the highest crash rates. Across this mix of highway types, crash rates differ by at least a factor of 3 or 4 between typical rural two-lane highways and rural freeways.

The relationship of congestion to safety is complex and not well defined. Most believe that congested roads are less safe, but the data are unclear and conflicting. Smooth traffic flow at high levels of service seems most consistent with safety. Congestion creates turbulence in the traffic stream and can create speed differentials that lead to crashes. But on that kind of facility, speeds are also often lower and the consequences of collisions may be less severe.

Diversion of trucks from a freeway to a toll road will probably not affect safety much, if at all. However, where diversion of trucks takes place from a limited-access highway to a conventional highway, either to avoid congestion on the limited-access highway or to avoid a toll on a toll road, it is clear that collision frequencies will increase and collision severity may also increase, although that is less well quantified.

Vehicle Design and Operations

Safety enhancements may require improving the compatibility among the vehicle, the roadway, and the operation of the system. The essential vehicle components for consideration include

- Vehicle length, turning radii, width, height, horsepower, and weight;
- Lane width;
- Maximum and minimum grades; and
- Radius of curvature.

Issues involving operations are equally important. Research is ongoing with respect to vectoring trucks through intersections and onto freeways safely.

Research Needs

Gerald Donaldson

Established standards for roads that carry heavy-truck traffic.

Douglas Harwood

- The extent to which highway design is addressing the types of vehicles that are on the roadway systems.
- The interaction among vehicles and multiple geometric design elements.
- Roadway classifications that drivers and carriers typically use when comparing crash rates.
- Relationship between safety and congestion.

Dan Middleton

- Methods for improving truck travel through intersections.
- Optimum use of in-vehicle devices.
- Fair and equitable tolls.
- Standards for the appropriate use of onboard diagnostics.

Edward Fekpe

- Separating trucks and cars:
  - –Design, performance standards, and methods for evaluating exclusive truck lanes (ETLs),
  - –Impacts of ETLs on safety,
  - –Impacts of ETLs on congestion,
  - –Logistics costs and user costs (e.g., value of time), and
  - –Financing ETLs, for example, tolls.
- Methodology to estimate capacity of rail.
- Freight movement patterns, temporal and spatial.
- Potential safety and other impacts of diversion.

Impact of Highway and Interstate Funding Policy Decisions on Truck Safety and Truck-Involved Crashes

Future Research Needs

Jeffrey Short

The Highway Trust Fund (HTF) was created in 1956 as a source of financing for the United States Interstate system through several taxes and fees. Although the HTF was initially created to build and support the Interstate system, money from this fund now supports many diverse transportation and transportation-related projects including programs for safety, air quality, and mass transit. The HTF monies are currently separated into two accounts: the Highway Account and the Mass Transit Account. Each year over $35 billion is collected by the fund through the following means:

- Federal excise tax on fuel (per gallon: gasoline, 18.4¢; gasohol, 13¢; and diesel, 24.4¢),
- Federal excise tax on tires (for tires over 40 lb),
- Federal excise tax on truck sales (12%),
- Federal excise tax on trailer sales (12%), and
- Heavy-vehicle use tax (annually, $100 + $22 for every 1,000 lb over 55,000 lb).

The majority of these funds are raised through the excise tax on fuels. Therefore, those who drive automobiles and trucks fund the National Highway System (NHS) and many programs that are transportation-related.

Though billions are collected from the users of surface transportation through these taxes, there remains a deficiency in funding throughout the NHS for necessary highway maintenance and additional infrastructure. This shortfall has resulted from several complications in highway funding. Central to this is the fact that excise taxes on fuels remain constant and are not adjusted for inflation. With fuels as the central source of funding for the HTF, the annual revenues of this fund have remained relatively constant whereas the costs, because of inflation, have increased. This situation has been exacerbated by recent trends away from low-fuel economy vehicles to hybrid and other fuel-efficient means of transportation.

Thus, the funding burden falls to entities outside the HTF, and state governments must provide more revenue toward the total needed for road maintenance and new infrastructure each year. To ease the financial burden of the aforementioned activities, states have indicated an interest in tolling existing Interstates and highways, creating new tolled infrastructure, and increasing current toll rates for both trucks and automobiles.

Trucking Industry

Nine billion tons of freight are currently shipped by truck each year in the United States. The American Trucking Associations (ATA) estimates that truck shipments will grow on average at a rate of 2.6% annually between 2004 and 2015, resulting in future annual shipments of more than 12 billion tons. Thus, trucking is an integral component of the U.S. economy, and demand for the industry's services is growing. Although this growth may indicate the potential for high profit margins for truck carriers, the deregulation of the 1980s has allowed for competition among trucking firms to become intense, putting considerable pressure on operating margins. More specifically, deregulation lowered barriers to entry such as operating authority and financial viability and thus led to growth in registered carriers from fewer than 20,000 to more than 585,000; the effect of this increased competition has reduced net operating margins (after income and taxes) to 1.4% to 3.08% (*American Trucking Trends* 2003). Additional factors that affect a carrier's financial health include

- Competition among other freight-transporting sectors,
- Economic recessions,
- Driver shortages,
- Volatile and increasing fuel costs, and
- Skyrocketing insurance rates.

Trucking and Tolls

Facing tight competition, truck carriers have had to lower costs and subsequently prices to gain market share. As a result, there is now a dichotomy between carriers that avoid cost by operating in a less safe manner and those that invest in accident prevention technologies and methods and therefore may have to charge more than those who do not view safety as a concern. Likewise, if a carrier can save money by avoiding interstate tolls through the use of parallel secondary roads or alternate highway routes, competition among carriers can involve operational cost cutting. Thus, there are trucks that will avoid toll roads, such as Interstate 76 in Pennsylvania (Pennsylvania Turnpike), to avoid the $150, or 42¢ per mile, that is charged to cross the state from New Jersey to Ohio. Often these carriers do so at the cost of both safety and efficiency.

The buyers of freight transportation are often willing to accept certain additional costs that are passed along by the carrier, for instance, a fuel surcharge. Shippers understand that there is at least a general increase in fuel costs and are therefore willing to pay the surcharge. However, shippers are not as willing to accept a toll surcharge because there are motor carriers that will not pass toll costs on and because it is not a widespread issue. In the case of Interstate tolling, most tolled Interstates can be found between Maine and Illinois, with the most extensive systems in Indiana, Ohio, Pennsylvania, New York, New Jersey, and Massachusetts. Thus, a large portion of the country is not as familiar with tolling as those who live in the northeastern quadrant of the United States. Many carriers can be unevenly affected by tolls as a result of their physical location and the route choices made to conduct business.

All these factors lead to avoidance of tolls and choice of free alternatives, such as parallel secondary roads or less direct and often more congested alternate routes, by trucks in varying degrees. This situation can lead to increases in truck-involved crashes due to greater numbers of trucks on roads that were not designed to facilitate nonlocal truck movements. Also, less direct routes may increase truck-involved crashes because these routes are often more congested, for example, Interstate 95 as an alternative to the Florida Turnpike. Greater vehicle miles traveled (VMT), especially in a congested area, may also increase the likelihood of a truck-involved accident.

Safety and Highway Funding Research Needs

HTF Issues: Are Revenues Properly Allocated?

The safety issue discussed here is avoidance of toll roads, which are designed for truck use, by trucks and their use instead of less direct and more congested routes or parallel secondary roads, which were not designed for heavy-truck traffic. One reason for the existence of toll roads, and the subsequent toll increases, is a lack of adequate funding for roadway design, construction, and maintenance. The HTF is not able to provide an adequate level of funding for a variety of reasons, including the use of HTF monies for purposes outside the original intent of the fund. Research therefore should be conducted regarding the future allocation of HTF revenues, addressing the following issues:

- A comparative analysis of HTF resource allocation for highway and nonhighway uses and
- A cost-benefit analysis of HTF funding categories and the relative impact on safety and efficiency.

HTF Options: Rethinking Source of HTF Revenue

As stated earlier, the push for adding tolls to existing roads and for allowing increases of current tolls exists to some degree because the HTF allocations are not substantial enough for required maintenance and infrastructure improvements. One of the major contributors to this fund, the federal excise tax on fuels, has remained the same since October 1993, at 18.4¢ per gallon for gasoline and 24.4¢ per gallon for diesel (there was a brief decrease of 0.1¢ per gallon between 1996 and 1997). Since it is a cost per gallon rate, the tax is not subject to inflation. As fuel costs rise, the percentage of tax paid per gallon falls. Therefore, there are only two situations in which an increase in revenues collected by the HTF from gasoline and diesel consumption can occur: if consumption of these fuels rises and if the tax rate per gallon increases.

It is also important for researchers to consider other methods of funding the HTF. Currently large trucks pay a considerable portion of total highway user taxes; as a percentage of the total HTF contributions, trucks accounted for 42% in 2003. Motor carriers pay a 12% tax on new vehicles, yet automobiles, whose purchasers use the same roads and benefit from the same highway maintenance and new infrastructure, do not contribute comparable taxes to the HTF. Likewise, increases in the gasoline tax, which is nearly 25% less than the diesel tax, could allow for a more even distribution of highway funding burdens and could greatly increase the revenue generated for the HTF. Future research should answer the following questions:

- What level of increase in the federal excise tax on fuel is necessary to generate the required revenues for adequate highway funding?
- Are there additional sources of revenue for the HTF?
- Should the fuel tax be tied to inflation?
- Are the current funding formulas equitable for all highway users?

Truck Diversion in Response to Tolls and Toll Policy Choices

If alternate routes exist for highways and the users of those highways are subject to tolls, it is likely that some drivers will choose the "free" alternative. This choice may be made without consideration of the potential decreases in efficiency and safety. However, the result of this truck diversion is not fully understood.

Anecdotally, it can be said that a degree of safety is lost when a truck leaves a toll road and chooses a route on a local road. When using a toll road, a truck enters the highway, sets a speed, and does not stop until the final toll booth. All traffic near the truck is going in the same direction at a relatively similar speed. Vehicles do not enter the highway from a complete stop off a perpendicular road. There are no stop lights. A parallel road has just the opposite conditions. Stops and starts can be frequent. Anything from pedestrians to bicyclists to slow-moving farm equipment may appear over the next hill. Turns are not gradual, cars enter and leave the road constantly, and traffic moving in the opposite direction passes within feet of a truck that potentially weighs 80,000 lb. Although these conditions may be representative of what actually exists regarding the different degrees of safety on each road, research is needed in the following areas:

- What is the crash experience of trucks that use secondary or parallel roads when a toll road exists?
- What are the design features of the secondary or parallel roads that might contribute to the crash experience of large trucks?
- To what degree can the crash experience be attributed to road design on the alternate routes?
- The size of this safety problem should also be considered by researchers. A determination of the extent to which this problem exists is necessary. Currently, of the 42,793 mi of Interstate, only 2,814 mi are subject to tolls (6.5%). There are another 1,785 mi of non-Interstate highway toll road in the United States. What impact do these 4,599 mi of toll road have on truck safety?
- An overall study should be undertaken of truck crash rates on diversion roads parallel to all toll roads.
- Those rates must be compared with rates on similar roads that are alternative routes to highways but not alternative routes to toll highways.

Understanding that the prices for different toll highways vary greatly, one must consider the supply and demand of toll roads and the impact of economics on diversion from these roads. Policy makers who set the price on tolls without considering market forces risk the unintended consequence of creating unsafe operating conditions. The basis of economics is supply and demand. The supply of a toll road is limited to the capacity of the road. In some cases tolls are needed to change demand, as in the case in which so many vehicles are using a road that the congestion level results in suffocating inefficiencies. Many of the toll roads in existence today, however, are not anywhere near capacity and are in fact used only to generate revenue. The demand for toll roads is based on price and the availability of alternatives. Figure 1 shows a normal demand slope and the effect of price on number of trucks on the Interstate. As the price doubles (price × 2*)*, the number of trucks overall that use the interstate decreases.

The demand curve (demand for Interstate) does not always fall as it does in Figure 1. A major factor is the supply of alternatives to the highway. Truck routes, especially those over long distances, can vary greatly to avoid tolls. A truck driver may choose the congested yet free alternative of I-95 to I-85 in Virginia instead of taking an I-81 route, where tolls may exist in the future. Likewise, the closer alternatives of parallel roads will attract customers away from the tolled Interstates and highways.

Thus, alternatives affect how many trucks enter a toll road at a given price and thus the elasticity of demand for that Interstate. A highway with many alternatives might have a more horizontal, or elastic, demand curve. In the case of a more elastic demand curve, as prices move slightly higher, the cliché "the straw that breaks the camel's back" holds true. Slight movements upward in price have large effects on truck driver diversion. In fact, depending on how elastic the supply curve is, increases can drive so many trucks away that the toll road actually experiences a decrease in revenue. With that decreased revenue is an added decrease in societal

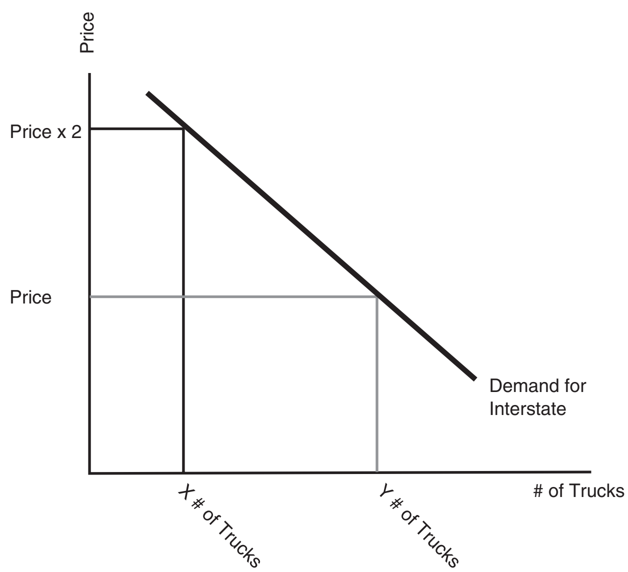

FIGURE 1 Demand for toll Interstate.

benefit: less safe parallel local roads that may result in injury and fatalities and less safe toll-free highway and Interstate alternatives because of increases in congestion. Thus, both supply and demand research are necessary, as well as cost-benefit research.

Research on driver behavior should be conducted to determine further why drivers make choices about paying or avoiding tolls and to gain a better understanding of what the elasticity of demand for toll roads actually is. What are the pressures on the drivers and trucking companies by the customer to avoid toll roads? Are customers willing to pay for tolls as they are for a fuel surcharge, and if not, will they therefore get the best pricing from the trucking company that avoids tolls?

It should also be determined if tolls directly affect drivers financially and, if so, which type of drivers tolls affect the most. Although larger carriers may cover costs such as tolls, a majority of trucking companies have seven power units or fewer and many function as owner–operators. Driver interviews could determine if these smaller companies cover these costs or if the driver must pay out of pocket and thus have an incentive to avoid tolls.

Research must also determine driver behavior based on perception of tolls. What percentage of drivers will avoid any toll regardless of cost? What reasons do drivers have for doing so? Is this category of driver aware that it may in fact be far more expensive to avoid toll roads? Finally, for those drivers who are willing to pay a toll, at what point will the driver move from the toll road and onto less safe secondary roads?

Finally, do drivers behave differently when they are on roads that run parallel to toll roads? Though they are saving money by avoiding the toll, it is obvious that operationally parallel roads are less efficient. Therefore, there is the potential for drivers to behave as if they are in a rush, possibly taking risks as they are driving.

Truck-Only Toll Lanes and Truck-Only Roads

Two options have arisen in recent years for funding increased truck capacity: truck-only toll lanes and truck-only toll roads. What, if anything, is the impact of these practices on safety? Truck-only toll lanes and toll roads could increase safety but could also decrease safety, depending on the overall design of the new infrastructure. Several questions are crucial to these options:

- Is the toll lane or toll road mandatory? If there is no free alternative on the same highway, would parallel routes offer a free, less safe alternative?
- How congested is the current infrastructure on which the truck-only lane or road would be located? If it is congested, would there be both safety benefits and operational benefits from new infrastructure?
- Pricing would also be of concern. It is important to price the road or lane in a way that encourages trucks to use roads as opposed to free alternatives, which may not provide a comparable level of safety.
- Is there a demand for truck-only toll lanes and roads? Urban areas, with higher levels of congestion, may be more successful with this type of infrastructure funding program than rural areas.
- What are the overall safety benefits of increasing the capacity through new lanes or roads that are part of existing roads?

Capacity Crisis

The last question leads to necessary research on the safety impact of not increasing capacity. Congested roadways can lead to more accidents and more diversion from free Interstate and highway roads simply to avoid congestion. As traffic increases and highway capacity remains stagnant, there are more bottlenecks, more sudden stops, more lane shifts, and potentially an increase in crashes and truck-involved crashes. These, in turn, lead to secondary crashes as highway lanes are closed, traffic queues back up, and traffic is forced to stop suddenly, which often causes severe rear-end crashes. The following research should be considered to determine the effects of capacity on safety:

- What is the relationship between congestion and safety?
- Absent new capacity, what will be the safety impact of increased car and truck travel?

• Do trucks divert onto parallel local roads simply to avoid highway congestion?

Conclusion

The Connecticut Department of Transportation, in its history (published on its website), states: "The removal of tollbooths did improve travel time and safety, but also reduced revenue for the Transportation Fund and impacted over 400 people who lost their jobs" (*Connecticut DOT History*, Chapter 9). The removal of all tolls from the highways and bridges in Connecticut was in response to a crash at a toll booth on the Connecticut Turnpike that resulted in seven fatalities.

Although 400 people who collect tolls may have lost their jobs in Connecticut, and thousands more would lose their jobs if all toll roads were eliminated, research over the next 5 to 20 years may reveal a much more serious consequence: the number of lives lost due to highway funding choices that force trucks onto unsafe alternative routes.

The State of Ohio recently came to a new conclusion regarding tolls and similar topics covered here. Recognizing the benefit of implementing strategies to improve safety by reducing truck traffic on routes parallel to the Ohio Turnpike (*Taft Plan to Improve Safey and Mobility in Northern Ohio*), the state provided an incentive to use of the turnpike by drastically cutting the toll rate by more than 50% for trucks. In addition, the state decreased the speed differential between trucks and cars by increasing the speed limit for trucks, providing an additional safety benefit for trucks using the turnpike.

In conducting research on the safety implications highway funding choices have for trucks, perhaps better designs for highway funding will develop in other states, and choices that degrade safety will not be made. The research therefore may have the following results:

• The HTF may benefit from more effective resource allocation practices.

• Appropriate pricing of toll roads and a full understanding of the safety implications of highway funding policy choices may exist.

• A safety-conscious and optional approach to increasing infrastructure with toll revenues may be realized.

• An understanding of the safety impacts of highway congestion and highway capacity may develop.

Liability and Acceptance of New Technology

Frederick Sager, Jr., *Weinberg, Wheeler, Hudgins, Gunn and Dial, LLC*
John H. Siebert, *Owner-Operator Independent Drivers Association Foundation*
Robert Corry, *Corry, Porter & Smith, LLP, Provocateur*
John Berry, *FedEx Freight, Moderator*

Future Scenario

Robert Corry

- Tort reform:
  - Fewer lawsuits,
  - Focus on large cases.
- Lawsuits aimed at truckload carriers not less-than-truckload carriers.
- Larger-truckload carriers invest in technology because it makes sense and they understand that safety pays off.

Frederick Sager, Jr.

- Tort reform, liability caps, and the expense of trying medical malpractice cases will encourage more and bigger lawsuits against trucking companies.
- Venue provisions will force bringing lawsuits where the accidents occur, which will decrease "judge shopping."
- There will be some reduction in frivolous lawsuits.
- Generally trials will be fairer and the judges will become better gatekeepers in terms of information that can be presented in court.
- Accident investigation will be somewhat less important because there will be more reliance on technology and less on expert witnesses.

The focus of future litigation will be on truckload carriers (TLCs) because the drivers are relatively young and inexperienced and job turnover is frequent. The characteristics are not conducive to building a culture of safety at the individual or organizational level. Because there is a natural tension between operations and safety, many unfit drivers slip between the cracks. None of this will be resolved until something is done about the pay-by-mile system, which encourages drivers to speed and violate hours-of-service rules.

Addressing the driver pay issue will have the largest impact on safety improvement. Better pay will encourage driving as a career and attract more mature, professional workers. Shippers should share in the cost of safety and help compensate drivers. Currently, shippers bear none of the responsibility, and contracts between shippers and motor carriers are one-way with shippers being protected and absolved of any responsibility.

Currently, the federally mandated minimum liability insurance for most motor carriers is $750,000. This requirement has been on the books for many years, and it may be time to increase the limit. Since insurers monitor carrier accident frequency and severity, the insurance market provides a barometer for motor carrier safety. Although some marginal insurers (and even some standard companies) are willing to write minimum-limits coverage for almost any regulated motor carrier, higher mandatory minimum insurance limits would make these insurers think twice before issuing policies to carriers with poor safety records. Top-end motor carriers already maintain coverage far in excess of the current mandatory minimum limit, for example, $10,000,000 to $100,000,000 or more. An increase in the minimum coverage required would not affect them; however, marginal (unsafe) carriers would be forced to improve their safety programs or go out of business.

There is a direct correlation between driver compensation and safety. Higher-paid drivers tend to be older, experienced professionals, whereas those at the low end of the pay scale are typically young and inexperienced. There is a high concentration of younger drivers in the truckload segment of the industry. They are invariably paid by the mile. A premium is placed on long hours behind the wheel. Since the large shippers effectively set the rates for transportation of their goods and carriers' profit margins are thin, driver compensation in the truckload segment is effectively capped by shippers. Long hours away from home and low pay lead to driver turnover rates exceeding 100%. These relatively young and inexperienced drivers account for a disproportionate number of accidents.

Shippers are the ultimate beneficiaries of low driver compensation because they bear no responsibility for the human and financial losses resulting from crashes. This situation could be addressed by a regulation mandating shared liability by shippers while their goods are in transit. Furthermore, the abolition of oppressive "hold harmless" and indemnity agreements required by some shippers should be reviewed. In summary, if shippers are required to share in the losses resulting from accidents caused by young, inexperienced, and underpaid drivers, they would be forced to become partners in safety with the motor carriers who transport their goods.

Another approach would be to revisit the current motor carrier ratings of satisfactory, conditional, and unsatisfactory. This pass-or-fail approach does little to encourage safety. Consideration should be given to rating carriers according to their safety records and levels of liability insurance. For example, Class A carriers could be required to have a low DOT-recordable accident rate and higher liability insurance coverage. This would encourage motor carriers to hire and retain mature professional drivers at higher levels of compensation. If shippers chose to utilize carriers in lower safety classifications, they could be required to provide excess liability insurance, equal to that mandated for Class A carriers. One way or another, shippers should share the benefits and burdens flowing from the quality of their motor carriers' safety programs. This requirement would place such shippers on an equal footing with those who maintain fleets for distribution of their products.

Many motor carriers do not understand the extent to which safety affects the bottom line. Although the larger TLCs will invest in technology, the smaller TLCs will not do anything unless mandated by law or regulation. Smaller LTLs move from terminal to terminal, so there is no real need to communicate with the truck on the road. They will not see a benefit in using technology. In any event, all truckers will be very leery of any technology that could bring them harm. Therefore, Congress and other regulators should focus on providing incentives for using data recorders to improve the data used for identifying crash causation factors.

Panel Discussion

Frederick Sager, Jr., and John H. Siebert

- Shippers, receivers, and perhaps even brokers should share in the liability costs.
- Leasing regulations indemnify the company; they should protect the drivers as well.
- The reality is that workers are attracted to professional truck driving because of the freedom it allows. They view the installation of technology as a sign of distrust.
- Technology is a mixed blessing. A Michigan study of owner–operators showed that truckers with GPS technology earned 16% more than their counterparts without the technology; however, they had to drive 24% more miles to pay for it.
- The idea of a "professional driver" may not be realistic in today's economy because young people don't stay in any one career or job for more than a few years, if that.

Closing Observations

Susan Herbel, who served as consultant to the conference committee, provided some closing observations on the two-day proceedings.

Future Characteristics

As the presentation and discussion of future scenarios at the conference made clear, it is difficult to predict the future. Caution is advised because predicting the future and making policy and investment decisions based on an expected scenario may well change the future itself in ways that are not necessarily desirable.

Population Characteristics

The future population can be expected to be larger, older, more affluent, better educated, and highly mobile. These characteristics will have an impact on transportation investment decisions and other factors, such as congestion and air quality. It is clear that the population is aging; however, the older population will differ from today's older population, and the impact the phenomenon will have on the industry is unclear. For example, until recently, about one-third of women never drove or held a driver's license. By the time the baby boomers get to be 65 and older, as many women will be licensed to drive as men. They will be experienced drivers, and the mix of vehicles and trip types will look quite different than it does today. Older people tend to be more fearful of driving around large vehicles and may react negatively to increasing truck travel.

Truck and Bus Travel

Freight movements are likely at least to double by 2025, and there will be many more trucks and buses on the road. Trucking will remain highly competitive, with many new entrants each year, and carrier consolidations will increase. Many anticipate that trucks will be bigger and perhaps heavier, which will have implications for the aging infrastructure. The need for regulation and inspection will continue. Technology development will continue, and the issue over who owns the data collected by onboard recorders and other devices will not be easily resolved.

Drivers

The shortage of qualified, professional drivers can be expected to remain a serious issue unless there are changes made to the pay scale and work hours. Greater government and industry focus on driver health, safety, and security could yield a substantial payoff in terms of safety as well as driver recruitment and retention.

General Research Needs

Participants cited and discussed a wide range of research opportunities. The following general research needs were among those most frequently noted at the conference:

- More and better data;

- A realistic understanding of how to use research results before studies are conducted;.
- Better or different research methods that include solution of some of the exposure problems;
- Alternative designs and methods for moving freight;
- Models for improving efficiency in trucking;
- Development of effectiveness- and cost-benefit analysis for absolutely everything;
- Studies of market forces and how they affect the trucking industry;
- Examination of the chain of command in the industry and clear definition of roles and responsibilities;
- Vehicle ergonomics, health, wellness, safety, and injury prevention;
- Identification of high-risk drivers;
- Effective driver and carrier incentives for safe driving; and
- Multivariate analysis of crash avoidance techniques in vehicles and methods for ensuring their use.

Other Issues

Other issues to be addressed were noted by some conference participants:

- Understanding the problem. This is critical as a point of departure. The conference was heavily focused on solutions. It was suggested that more emphasis needs to be placed on understanding the nature and elements of the problem, for example, crash causation, hours of service, driver qualifications and pay.
- Addressing the safety and security of buses and transit for drivers and passengers.
- Identifying collaborative funding models to meet the research needs.
- Developing a roadmap or some other action plan for implementing and tracking the ideas generated from the conference.
- Keeping the conference participants involved and engaged.

APPENDIX A

Agenda

March 23–24, 2005

MARCH 23, WEDNESDAY

8:00 a.m.–8:15 a.m.	**Welcome and Introductions** Richard Pain, TRB H. Douglas Robertson, University of North Carolina Highway Safety Research Center, and Chair, Committee for a Conference on Future Truck and Bus Safety Research Opportunities
8:15 a.m.–8:45 a.m.	**Conference Theme and Challenge** Stephen M. Millett, Battelle Memorial Institute *Thinking About the Future of Truck and Bus Safety*
8:45 a.m.–10:15 a.m.	**Problem Assessment: The Look of the Freight Future and Truck and Bus Safety**
Moderator:	H. Douglas Robertson
Provocateurs:	Alan Pisarski, Consultant Kenneth Campbell, Oak Ridge National Laboratory
Panelists:	John H. Siebert, Owner-Operator Independent Drivers Association Foundation Thomas Corsi, University of Maryland Clyde Hart, American Bus Association John Berry, FedEx Freight
10:45 a.m.–12:15 p.m.	**Human Performance, Capability, and Behavior**
Moderator:	Anne T. McCartt, Insurance Institute for Highway Safety
Paper Presentation:	High-Risk Commercial Motor Vehicle Drivers and Differential Crash Risk: Future Directions Jeffrey S. Hickman
Provocateur:	Richard Hanowski, Virginia Tech Transportation Institute
Panelists:	Azim Eskandarian, George Washington University Forrest Council, Highway Safety Research Center David F. Dinges, University of Pennsylvania School of Medicine Gerald Krueger, Wexford Group International
1:00 p.m.–2:30 p.m.	**Enforcement, Compliance, and Security Management**
Moderator:	Stephen Campbell, Commercial Vehicle Safety Alliance

Paper Presentations:	Research Required to Ensure Appropriate Maintenance and Compliance for Safe Operation of Commercial Motor Vehicles in the Year 2025 S. J. Shaffer, D. M. Freund, L. W. Loy, and L. W. Minor Enforcement, Security, and Future Research Ronald Hughes, Stephen Keppler, Skip Yeakel, Conal Deedy, Tom Moses, and Charles Carden
Provocateur:	Donald Osterberg, Schneider National, Inc.
Panelists:	John H. Siebert, Owner-Operator Independent Drivers Association Foundation Donald Bridge, Jr., Connecticut Department of Motor Vehicles William Mahorney, American Bus Association
3:00 p.m.–4:30 p.m.	HEALTH AND WELLNESS
Moderator:	E. Lee Husting, National Institute of Occupational Safety and Health
Paper Presentation:	Future Truck and Bus Safety Research Opportunities—Health and Wellness E. Lee Husting
Provocateur:	Michael Belzer, Wayne State University
Panelists:	Edward Hitchcock, National Institute of Occupational Safety and Health LaMont Byrd, Teamsters Union Donald Osterberg, Schneider National, Inc. Mark Rosekind, Alertness Solutions
5:30 p.m.–7:00 p.m.	RECEPTION

MARCH 24, THURSDAY

8:00 a.m.–9:00 a.m.	THE FUTURE TRUCK AND BUS WORKFORCE: COMPOSITION, SKILLS, TRAINING, AND SECURITY
Moderator:	Kevin Lewis, American Association of Motor Vehicle Administrators
Paper Presentations:	Future Simulation Technology for Future Safety Demands in the Truck and Bus Industries Jerry Wachtel, Konstantin Sizov, Donald Fisher, Ronald Mourant, and Christopher Crean Analysis and Use of Commercial Vehicle Driver Conviction Data Brenda Lantz
Provocateur:	Kevin Lewis, American Association of Motor Vehicle Administrators
Panelists:	Rebecca Brewster, American Transportation Research Institute Richard Clemente, Professional Truck Driver Institute, Inc.
9:00 a.m.–11:00 a.m.	VEHICLE DESIGN AND TECHNOLOGY
Moderator:	Robert Clarke, Truck Manufacturers Association

Paper Presentation:	Utilizing Future Vehicle Technology to Improve Safety D. M. Freund, S. J. Shaffer, L. W. Loy, and L. W. Minor
Provocateur:	Peter Sweatman, University of Michigan Transportation Research Institute
Panelists:	Timothy Morscheck, Eaton Corp. Richard Beyer, Bendix Margaret Sullivan, PACCAR V. K. Sharma, International
11:00 a.m.–12:30 p.m.	**ROADWAY DESIGN AND OPERATIONS**
Moderator:	Alan Clayton, University of Manitoba
Paper Presentation:	The Implication of Highway Funding Policy on Truck Safety and Truck Involved Crash Jeffrey Short
Panelists:	Douglas Harwood, Midwest Research Institute Dan Middleton, Texas Transportation Institute Edward Fekpe, Battelle Memorial Institute Gerald Donaldson, Advocates for Highway Safety
12:30 p.m.–1:00 p.m.	BUFFET WORKING LUNCH
1:00 p.m.–2:15 p.m.	**LITIGATION, LIABILITY, COST OF CRASHES, AND ACCEPTANCE OF NEW TECHNOLOGY**
Moderator:	John Berry, FedEx Freight
Provocateur:	Robert E. Corry, Jr., Dennis, Corry, Porter & Smith, L.L.P.
Panelists:	Frederick N. Sager, Weinberg, Wheeler, Hudgins, Gunn & Dial, LLC John H. Siebert, Owner-Operator Independent Drivers Association Foundation
2:15 p.m.–2:45 p.m.	**SUMMARY AND ADJOURN**
Moderator:	H. Douglas Robertson
	CONFERENCE HIGHLIGHTS SUMMARY Susan Herbel, Cambridge Systematics and TRB Consultant
	CLOSING THOUGHTS
	ADJOURNMENT

APPENDIX B

Participants

Albert Alvarez
Project Manager
Federal Motor Carrier Safety Administration

Debra Anderson
Associate Professor
University of Kentucky College of Nursing

Michael Belzer
Professor
Wayne State University

John Berry
Vice President, Risk Management
FedEx Freight East

Richard Beyer
Manager, Technical Sales
Bendix Commercial Vehicle Systems LLC

Rebecca Brewster
President and Chief Operating Officer
American Transportation Research Institute

Donald Bridge, Jr.
Sergeant
Connecticut Department of Motor Vehicles

LaMont Byrd
Director, Safety and Health Department
Teamsters Union

Gianluigi Caldiera
Federal Motor Carrier Safety Administration

Kenneth Campbell
Program Manager Transportation Safety
Oak Ridge National Laboratory

Stephen Campbell
Executive Director
Commercial Vehicle Safety Alliance

Robert Clarke
President
Truck Manufacturers Association

Alan Clayton
Professor
University of Manitoba

Richard Clemente
Program Director
Professional Truck Driver Institute, Inc.

Joanice Cole
Senior Program Assistant
Transportation Research Board

Michael Conyngham
Director
International Brotherhood of Teamsters

Robert E. Corry, Jr.
Partner
Dennis, Corry, Porter & Smith LLP

Thomas Corsi
Professor
Robert H. Smith School of Business

Forrest Council
Senior Research Scientist
University of North Carolina Highway Safety Research Center

Robert Davis
Federal Highway Administration

David Dinges
Professor
University of Pennsylvania

Gerald Donaldson
Senior Research Director
Advocates for Highway And Auto Safety

Azim Eskandarian
Professor and Director
Center for Intelligent Transportation Systems
George Washington University

Edward Fekpe
Research Leader
Battelle Memorial Institute

D. M. Freund
Senior Transportation Specialist
Federal Motor Carrier Safety Administration

Alessandra Guariento
Senior Director of Safety and Security
Greyhound Lines, Inc.

Richard Hanowski
Research Scientist
Virginia Tech Transportation Institute

Clyde Hart, Jr.
Administrator
U.S. Maritime Administration

Douglas Harwood
Principal Traffic Engineer
Midwest Research Institute

Susan Herbel
Senior Associate
Cambridge Systematics

Jeffrey S. Hickman
Virginia Tech Transportation Institute

Edward Hitchcock
Research Psychologist
National Institute of Occupational Safety and Health

Ronald Hughes
Senior Research Psychologist
University of North Carolina Highway Safety Research Center

E. Lee Husting
Scientific Program Administrator
Intervention and Evaluation Team, National Institute for Occupational Safety and Health, Centers for Disease Control

Ronald Knipling
Senior Research Scientist
Virginia Tech Transportation Institute

Gerald Krueger
Research Ergonomist
Wexford Group International

Brenda Lantz
Program Director
North Dakota State University

Kevin Lewis
Commercial Driver's License Safety Director
American Association of Motor Vehicle Administrators

William Mahorney
Director of Safety and Regulatory Programs
American Bus Association

Anne T. McCartt
Vice President for Research
Insurance Institute for Highway Safety

Doug McKelvey
Chief, Technology Division
Federal Motor Carrier Safety Adminstration

Michele McMurtry
Senior Project Manager
National Transportation Safety Board

Dan Middleton
Program Manager
Texas Transportation Institute

Stephen Millett
Thought Leader
Battelle Memorial Institute

Timothy Morscheck
Vice President Technology
Eaton Corporation

Donald Osterberg
Vice President, Safety and Driver Training
Schneider National, Inc.

Richard Pain
Transportation Safety Coordinator
Transportation Research Board

John Pearson
Program Director
Council of Deputy Ministers Responsible for Transportation and Highway Safety, Canada

Duane Perrin
Truxpertise, LLC

Alan Pisarski
Consultant

H. Douglas Robertson
Director
University of North Carolina Highway Safety Research Center

Mark Rosekind
President and Chief Scientist
Alertness Solutions

Frederick N. Sager, Jr.
Attorney
Weinberg, Wheeler, Hudgins, Gunn and Dial, LLC

S. J. Shaffer
Senior Research Scientist
Battelle Memorial Institute

V. K. Sharma
Director
International Truck and Engine Corporation

Jeffrey Short
Senior Research Associate
American Transportation Research Institute

John H. Siebert
Team Leader
Owner-Operator Independent Drivers Association Foundation

Margaret Sullivan
Director, Advanced Technology
PACCAR Inc.

Peter Sweatman
Director and Research Scientist
University of Maryland Transportation Research Institute

Jerry Wachtel
President
Veridian Group, Inc.

APPENDIX C

Abbreviations and Acronyms

ATA	American Trucking Associations
AAMVA	American Association of Motor Vehicle Administrators
C^3	command, control, and communication
CDC	Centers for Disease Control
CDL	commercial driver's license
CDLIS	Commercial Driver's License Information System
CMV	commercial motor vehicle
CVISN	Commercial Vehicle Information Systems and Networks
CVSA	Commercial Vehicle Safety Alliance
CWS	collision warning system
DOT	U.S. Department of Transportation
DSRC	dedicated short-range communication
ENS	employer notification system
ETL	exclusive truck lane
FARS	Fatality Analysis Reporting System
FCMSA	Federal Motor Carrier Safety Administration
F-SHRP	Future Strategic Highway Research Plan
GPS	Global Positioning System
HTF	Highway Trust Fund
IACP	International Association of Chiefs of Police
ISAC	Information Sharing and Analysis Center
ISS	Inspection Selection System
IVI	Intelligent Vehicle Initiative
LTL	less-than-truckload
MCMIS	Motor Carrier Management Information System
NCHRP	National Cooperative Highway Research Program
NRC	National Research Council
NIOSH	National Institute of Occupational Safety and Health
NORA	National Occupation Research Agenda
OBSM	onboard safety monitoring
OEM	original equipment manufacturer
OOIDA	Owner-Operator Independent Drivers Association
OOS	out of service
PACCAR	PACCAR, Inc
PBBT	performance-based brake tester
RFA	request for applications
RFID	radio frequency identification
SAE	Society for Automotive Engineers
SEA	safety evaluation area
TLC	truckload carrier
TMA	Truck Manufacturers Association
TRB	Transportation Research Board
VII	vehicle–infrastructure integration
VMT	vehicle miles of travel

APPENDIX D

Committee Biographical Information

H. Douglas Robertson, Chair, is Director of the University of North Carolina Highway Safety Research Center at Chapel Hill. He has 38 years of experience in transportation safety, engineering, and education. He is also a Research Associate Professor in the Health Behavior and Health Education Department of the University of North Carolina School of Public Health. Dr. Robertson has worked in the public, private, academic, and nonprofit arenas. In the public sector, he was Chief of the Programming Planning Division at the National Highway Traffic Safety Administration and Chief of the Systems Development Branch in the Accident Investigation Division. At the Federal Highway Administration, he was program manager for two major safety research and traffic engineering programs. He was a Professor of Civil Engineering at the University of North Carolina, Charlotte. In the nonprofit sector, he was Director of Programs and Budget for the Intelligent Transportation Society of America. He has also served as Vice President, Eastern Region, for TransCorp, a transportation engineering and consulting firm. Earlier he was a research scientist conducting traffic engineering and safety projects at BioTechnology, Inc. His extensive research, program management, and academic experience give Dr. Robertson broad expertise in many facets of transportation safety, with particular emphasis on the development and conduct of research strategies and programs. Dr. Robertson was chair of the TRB User Information Systems Committee and the Operations, Maintenance, and Safety Group Council. Most recently he chaired the TRB policy study School Transportation Safety Committee. He holds a B.S. in civil engineering from Clemson University, an M.S. in transportation engineering from the University of South Carolina, and a Ph.D. in civil engineering from the University of Maryland. He is a licensed professional engineer in Virginia and North Carolina. Dr. Robertson recently retired from the U.S. Army Reserve as a Major General.

John R. Berry is Vice President for Risk Management with FedEx Freight, where he is responsible for all aspects of driver and worker safety, insurance, cargo claims, health benefits, and worker compensation. He is a member of the Executive Committee, FedEx East. Before his 10 years with FedEx, Mr. Berry spent 14 years with McKesson Service Merchandising as Vice President of Human Resources. With 24 years of experience in all aspects of safety and risk management for very large trucking operations, Mr. Berry brings insight into the pragmatic, real-world issues confronting the trucking industry to the committee. Mr. Berry has a B.A. in accounting from the University of Arkansas.

Stephen F. Campbell, Sr., is Executive Director of the Commercial Vehicle Safety Alliance. He manages all aspects of the alliance, which represents all state and provincial agencies in Canada, the United States, and Mexico responsible for commercial motor vehicle enforcement in their jurisdictions. Before joining the alliance in 1999, he was Vice President for Safety, Training and Technology at the American Trucking Associations. Before coming to ATA, Mr. Campbell spent 14 years as a sworn officer with the Louisiana State Patrol, most recently as an Executive Officer. Throughout his career Mr. Campbell has dealt with every aspect of commercial motor vehicle safety. His experience ranges from specialized expertise with hazardous materials to dealing with national regulation and legislation of the motor carrier industry. The enforcement perspective is a key element in the future of the motor carrier safety. Mr. Campbell brings the knowledge and awareness of issues facing all the states plus the countries north and south of the United States. He chairs the TRB Commercial Truck and Bus Safety Synthesis Program Panel and is a member of the Truck and Bus Safety Committee. He is past chair of the National Safety Council Commercial Vehicle Section and is currently on its Board of Delegates, where he chairs the Highway Traffic Safety Venue Committee. He has a B.S. in criminal justice from Louisiana State University and a Police Administration Training Program Diploma from the Northwestern University Traffic Institute. He has certificates and diplomas from eight additional specialized training programs and courses.

Robert M. Clarke is Executive Director of the Truck Manufacturers Association. TMA represents all major North American medium- and heavy-truck manufacturers. This group focuses on safety, environmental, and energy-related regulatory and legislative issues. Mr. Clarke also directs cooperative research programs with TMA members and the government. Before joining TMA, Mr. Clarke spent 31 years with the federal government. At the U.S. Department of Transportation he served in safety-related research and policy formulation positions with the Bureau of Motor Carriers, Federal Highway Administration; National Highway Traffic Safety Administration; Federal Railroad Administration; and, finally, the Office of the Assistant Secretary for Transportation Policy. He brings a broad knowledge of truck issues to this committee and was a conduit to the expertise in the truck design and manufacturing industry in planning this conference. He has a B.S. in mechanical engineering from the Virginia Polytechnic Institute and State University and an M.S. in industrial engineering and human factors from the University of Michigan. He is a past chair and currently serves on the TRB Truck Size and Weight Committee. He is a former chair and current member of the Society of Automotive Engineers Truck and Bus Council.

Alan M. Clayton is Professor of Civil Engineering at the University of Manitoba. During his 35-year career, Mr. Clayton's principal research and professional interests and work have involved freight transportation, trucking, transportation safety, traffic and transportation information systems, intermodal freight transport, and spatial data technologies. He has dealt with infrastructure, freight and logistics, information systems, and safety issues through research and consulting. He ties his academic knowledge with real-world practice through his consulting to a wide variety of government and private-sector organizations. He is active on TRB truck committees and has organized the Manitoba Truck Safety Symposium biannually since 1995. Mr. Clayton brings broad knowledge of current and past research in all aspects of highway and truck issues. He has an M.S. in engineering from the University of Saskatchewan. In 2000, he was given a Lifetime Achievement Award from the Manitoba Public Insurance Corporation in recognition of his commitment and contribution to road safety. He is also a registered professional engineer.

Michael E. Conyngham is Director of Research for the International Brotherhood of Teamsters. He is responsible for coordinating the research activities of the union, including oversight of the 20-member research staff. He has performed research in freight and small package industries and is familiar with the issues currently and potentially facing the trucking industry, specifically as they affect the union membership. For this committee he brings the perspective of union-member truck and bus drivers, a perspective distinct from the independent owner–operator viewpoint. Mr. Conyngham is active on the TRB Trucking Industry Research Task Force. He is a member of the American Trucking Research Institute and serves as a member of the Labor Research Advisory Committee, Bureau of Labor Statistics. He has a B.A. in sociology from Notre Dame University and an M.A. in social work from the National Catholic School of Social Service.

Alessandro Guariento currently is Director of Safety for Greyhound Lines, Inc. He manages all safety-related activities for the company. He develops policies, programs, and procedures for accident and injury reduction and loss prevention. He is responsible for company compliance with U.S. Department of Transportation and Occupational Safety and Health Administration regulations. During his 10 years with Greyhound, Mr. Guariento has significantly reduced accident frequency rates, worker's compensation injuries, and driver out-of-service rates. His expertise and knowledge of the commercial interstate bus industry provide insight into their issues, current and future, and will contribute to committee understanding of the bus industry. His prior experience includes 10 years as an officer with the U.S. Army Transportation Command. Mr. Guariento has a B.S. in business administration from Oregon State University and certificates in operations research and traffic management control from the U.S. Army Logistics Management College and Army Transportation School. He is also a Certified Director of Safety, North American Transportation Management Institute.

E. Lee Husting is Chief of the Intervention and Evaluation Team, National Institute for Occupational Safety and Health, Centers for Disease Control. His team focuses on the prevention of occupational injuries, including work-related motor vehicle injuries and fatalities. Dr. Husting is working on commercial truck crash prevention and driver training evaluation. He is writing a book chapter on truck safety in the age of information sponsored by the Trucking Industry Program and Sloan Foundation. He chairs the ANSI Z15 Accredited Standards Committee on Safety Requirements for Motor Vehicle Fleet Operations and is a member of the TRB Trucking Industry Research Task Force. Dr. Husting's expertise in occupational and public health gives the committee insight into data and nontransportation types of expertise useful in conference planning. He has a Ph.D. in epidemiology from the University of London, an M.P.H. from the University of Pittsburgh, and a B.S. in zoology from the University of Michigan. Dr. Husting has served as adjunct professor for community medicine or public health at West Virginia University and the University of Miami. He also was Professor of Comprehensive Medicine at the University of South Florida. He is an elected Fellow of the American College of Epidemiology and the Royal Society of Tropical Medicine and Hygiene.

Ronald R. Knipling is Senior Research Scientist and Senior Transportation Fellow at the Virginia Tech Transportation Institute. There he serves as principal investigator or consultant on National Highway Traffic Safety Administration and National Cooperative Highway Research Program projects. These projects include syntheses of best practice in commercial vehicle safety management, guidelines for commercial vehicle safety operations, and intersection crash avoidance development. During his 25-year career, Dr. Knipling has served in research management positions with the National Highway Traffic Safety Administration and Federal Motor Carrier Safety Administration and as a consultant performing a wide range of research focused on diverse areas of highway safety. He brings a diversity of experience as both a research program manager and a research practitioner in motor carrier safety and, more broadly, highway safety. Dr. Knipling is the founding chair of the TRB Truck and Bus Safety Committee. Several years ago he was also the lead person in developing a truck and bus safety research agenda to complement the American Association of State Highway and Transportation Officials Strategic Highway Safety Plan. Dr. Knipling has a Ph.D. in experimental psychology from the University of Maryland and a B.A. in zoology from George Washington University.

Kevin Lewis is the Commercial Driver Licensing Safety Director for the American Association of Motor Vehicle Administrators. He is responsible for managing the CDL program as it relates to association, jurisdictional, and federal activities. He also defines areas of program research, safety information, and data required to facilitate development and maintenance of manuals, testing and training materials, and surveys concerning the CDL program. Before assuming this responsibility, Mr. Lewis implemented the American Association of Motor Vehicle Administrators net-based driver licensing systems and changes to those systems. He has worked as a computer analyst in several commercial settings and worked with computers during his 6 years with the U.S. Navy. Mr. Lewis is considered a national expert on commercial driver licensing. This expertise brings the issue of driver control and monitoring before the committee in planning the conference. Mr. Lewis has a B.S. in business management from the University of Maryland.

Anne T. McCartt is Vice President for Research with the Insurance Institute for Highway Safety, where she develops and directs research and evaluation projects in highway safety. She spent 3 years with the Preusser Research Group conducting a broad range of highway and traffic safety evaluation projects. For 17 years she conducted research for the Institute for Traffic Safety Management and Research at the Rockefeller College of Public Affairs and Policy of the State University of New York (SUNY) at Albany. This research included a wide range of highway and traffic safety topics with specific studies in commercial vehicle truck crash analyses, roadside safety inspections, use of limited-service rest areas, court dispositions of commercial driver tickets, and prevalence and risk factors for fatigue-related driving. She was Deputy Director of the Institute for 9 years. Dr. McCartt brings the insurance industry perspective in planning the conference on truck and bus future safety research. In addition, she brings a wealth of experience as a researcher in the field. Having served many years as Research Assistant and Associate Professor in the Departments of Public Administration and Policy and Department of Health Policy at SUNY Albany, she also brings the theoretical perspective to this committee. Dr. McCartt has a Ph.D. in public administration and policy and an M.L.S. and M.A. in secondary mathematics education from SUNY Albany. She also has a B.A. in mathematics and religion from Duke University. She is a member of the TRB Truck and Bus Safety Committee and Operator Education and Regulation Committee. She is active with the Association for the Advancement of Automotive Medicine and the International Council in Alcohol, Drugs and Traffic Safety.

John H. Siebert is Project Manager with the Owner-Operator Independent Drivers Association (OOIDA) Foundation, Inc. He is a research and communications and training specialist. He performs primary survey research concerning driver behavior and attitudes and produces educational materials and training modules specifically for independent truckers. Before joining OOIDA Foundation, Mr. Siebert spent 20 years in academic and corporate communications and training. Mr. Siebert represents the perspective of the independent truck owner–operator. Since this perspective is distinct from that of fleet operations, his understanding of and research concerning this type of truck driver operation is crucial to the committee. He holds a B.S., M.S., and Ed. Sp. in safety from Central Missouri State University.

TRB

TRANSPORTATION RESEARCH BOARD

500 Fifth Street, NW
Washington, DC 20001

www.TRB.org

ADDRESS SERVICE REQUESTED

PROCEEDINGS 38

Future Truck and Bus Safety Research Opportunities

ISBN 0-309-09422-4

TRB