Chapter 10

Truck Safety in the Age of Information

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Introduction

It is near dusk. An 80,000 pound tractor-trailer on a limited-access interstate makes an ascending left turn while climbing a grade in hilly terrain. The driver has been traveling all day and must maintain the maximum legal speed to reach the terminal before exceeding Federal Hours of Service Regulations. To maintain speed. the driver is forced to downshift repeatedly as the truck loses momentum on the rising grade. A call from dispatch flashes on the internal monitor. The setting sun flashes across the windshield, briefly obscuring vision, as the vehicle moves in and out of the shadows of the higher-elevation foothills. While the driver reflexively reaches for his sunglasses, a low–fuel light comes on. The truck builds up speed to climb the next rise. The road ahead curves more sharply as the truck rapidly approaches a turn that overloads the outside wheels. Over that rise, not yet visible. is a disaster in the making: Twelve car lengths ahead, an older van with weak rear lights and a nearly flat tire is struggling up the grade, at well below the minimum legal speed. Under a traditional scenario, the tractor-trailer would have struck the van in the next minute at best causing vehicular damage, at worst, losing lives.

A more palatable conclusion is possible using information and communication technologies developed in the last decade. A number of things occur in microsecond sequence: The on-board data manager recognizes time-functional hazards, suppresses the fuel warning light and dispatch call, allowing the driver to pay full attention, adjusts the windshield polarization to maximum visibility, records a hazard-data sequence from the sensor embedded in the highway, reduces the speed of the truck and adjusts the calibrators for the shock absorbers to prevent a rollover, and activates the Collision Warning System (CWS) indicators, flashing visual warnings and audible alerts to the driver.

The operator, now with the vehicle fully under control and with full visibility, brakes, downshifts, and steers the rig toward the break-down lane. The van is now immediately before him. The driver is unable to avoid contact, and the left front bumper strikes the van, forcing it across and off the road, where it comes to a halt. The truck maneuvers farther to the right and stops. Braking and vehicle status are captured in the on-board data recorder. No one in the van is seriously injured, but several of the passengers, none wearing seat belts, are shaken. The driver unbuckles the seat belt, sends a message describing the situation to the fleet dispatcher (who has already been electronically informed of the event and the location, along with the state police). Upon incident reconstruction, using data from the "black box," it is determined that the truck driver took immediate action to slow and to avoid a crash. The fortuitous outcome of this scenario could only happen with modern information technology used to improve roadway safety.

Trucks have been integral to the nation's transportation for decades. Commercial trucking safety and health have been affected both positively and negatively by new information and communication technologies. Although larger, more streamlined, and more powerful, the trucks of today remain recognizably similar to the earliest trucks. The internal systems and components have changed dramatically. The technological developments and innovations of the past century have transformed trucks from straightforward internal combustion driven vehicles with simple mechanical systems to sophisticated integrated systems with electro-mechanical, fuel, suspension, and transmission components dependent on advanced technologies. More recently, optimization routines, sophisticated relational databases, and advances in telecommunications have made trucks integral components of advanced transportation delivery systems.

Within the commercial trucking industry, the changes brought on by "The Age of Information" include advances in vehicle technology, systems integration, electronic communications, control technologies and scientific knowledge of human physiology have resulted in profound changes, affecting the way that commercial motor vehicles are operated, dispatched, tracked and managed. The ongoing evolution of these systems influences how driver safety and health is studied as well as the interventions which can be undertaken. Driver work/rest cycles can now be understood through data on human performance and fatigue. New information and communication technologies enable professional truck drivers and fleet managers to access data on the location, status, and overall functioning of vehicles, which can prove to be particularly helpful in the event of a crash. Drivers can plan, control, and adjust their routes and stops to coincide with traffic movement and to access available rest stops. Dispatchers can work more effectively with drivers to schedule arrivals and departures and load allocation. Newer information technologies can provide feedback on the physical status of the driver that can be used to help to prevent excessive fatigue or drowsy driving. Using these technologies directly impact the health and safety of truck drivers and indirectly improve safety for other vehicle drivers.

Improving the safety and health environment for the trucking industry requires multidisciplinary collaboration. Engineering, epidemiology, statistics, as well as the medical and social sciences provide necessary expertise. Implementing new technologies relies on the trucking community including drivers, fleets, government agencies, researchers and others. Measuring and monitoring the progress toward improved safety and health benefits from a structured process analysis. A scientific model employed by many public health agencies is referred to as The Public Health Model. It address issues from initial knowledge through effective solutions in five stages: Identification and prioritization of problems (surveillance), quantification and prioritization of risk factors (analytic research), identification of existing or development of strategies to prevent injuries (prevention and control), implementation of the most effective injury control measures (communication/dissemination/technology transfer) and monitoring the results of intervention efforts (evaluation).

Identify and Prioritize Problems (Surveillance)

Motor vehicle safety has been recognized as an important public health problem affecting both truck drivers and those in other vehicles for much of the last century. Identifying and prioritizing problems through analyzing surveillance data is the first step to reducing the occurrence of fatal and nonfatal trucking incidents.

Surveillance programs on truck crashes are maintained by state or federal government entities. The predominant federal agencies are the Federal Motor Carrier Safety Administration (FMCSA) and National Highway Traffic Safety Administration (NHTSA) within the Department of Transportation (DOT), the Bureau of Labor Statistics (BLS) within the Department of Labor (DOL), and the National Research Council (NRC). Although this data can be used to measure changes in the safety and health experience in trucking, differences in the missions of the organizations with surveillance programs, with consequent differences in purpose, jurisdiction and audiences, structural formats, and computer platforms result in incompatibility among programs and gaps in our information.

In 2001 there were more than 6.3 million police-reported motor vehicle traffic crashes, resulting in over 4.28 million property-damage-only crashes, over 3 million people injured, and more than 42 thousand people killed (NHTSA, 2002). With an average of 105 fatalities daily, motor vehicle crashes are the leading cause of death from unintentional injury in the general population (NHTSA, 2004). Moreover, deaths and injuries resulting from motor vehicle crashes disproportionately affected the younger population; they were the leading cause of death for ages 2 through 33 years (NHTSA, 2003).

Large trucks contribute substantially to motor vehicle crashes, well over 400,000 were involved in traffic crashes during 2002 (NHTSA, 2004). Almost 10%, or 4,542, of all vehicles involved in fatal crashes were large trucks. Drivers and passengers involved in these crashes accounted for nearly 5,000 deaths, 11% of all traffic fatalities in 2002. The numbers of large trucks involved in fatal crashes increased from 4,035 to 4,542 between 1992 and 2002; but, as the number of large trucks increased from 6 million to over 8 million, the crash experience decreased from 67 to 61 per 100,000 trucks between 1991 and 2001. The rate for fatal crashes dropped from 3 to 2, per million miles traveled between 1991 and 2002 (NHTSA, 2003).

Four per cent of all vehicles involved in nonfatal injury crashes were large trucks (NHTSA, 2004). The number of trucks involved in non-fatal injury crashes declined from 95,000 in 1992, to 94,000 in 2002, while the rate dropped from 62 to 43 per 100 million miles (NHTSA, 2003).

Detailed information on fatal and nonfatal work-related incidents is available from the Census of Fatal Occupational Injuries (CFOI) and the Survey of Occupational Injuries and Illnesses of the BLS. Despite annual fluctuations, highway incidents account for nearly one-fourth of fatal work injuries. From 1992 to 2001, highway transportation incidents were the leading cause of workplace death, with over 13,500 workers killed, an average of three worker deaths daily. Occupants of trucks accounted for nearly 60% of fatalities; almost half of these were semi-truck occupants (Pratt, 2003). During this period, trucks were involved in just over 7,700 or 58% of work-related incidents increasing from 50% to 64% between 1992 and 2001. Just under 50% of these trucks were identified as tractor-trailers (BLS, 2003).

Truck drivers accounted for 40%, of the fatal work-related highway incidents in the United States. Nearly two-thirds of the truck driver fatalities reported by CFOI were highway incidents. An additional 14% of driver fatalities were attributed to other transportation events such as railroad incidents, 8% were attributed to contact with objects and equipment, and 3% were assaults and violent acts.

Moreover, truck drivers are subject to frequent and serious injuries at work. Drivers had more lost-time workplace injuries and illnesses than any other occupation for each year from 1993 to 2001. In 2002 they experienced 129,000 work-related injuries and illnesses that required recuperation beyond the day of the incident. Drivers' incidents also tend to be severe. Nearly one-third resulted in missing 31 or more days. Truck drivers' median 10 days away from work compared unfavorably to the 6 days for all occupations (BLS, 2003).

Nearly 30%, of work-related truck driver incidents with days away from work were associated with overexertion. Falls were responsible for 20% of all truck driver incidents, just over 18% involved contact with objects and equipment while transportation incidents accounted for 13% of incidents. Musculoskeletal disorders, including sprains, strains, and tears comprised well over half of all truck driver incidents when categorized by the nature of injury or illness (BLS, 2003).

Despite the volume of surveillance data regarding motor vehicle and trucking incidents, each data system presents only a partial picture of the problem. Absent some means of linking these systems, it will be difficult to accurately quantify the safety benefits of technological advances or policy interventions on safety and health.

Quantify and Prioritize Risk Factors

The second step in the Public Health Model is to quantify and prioritize risk factors. This entails analytic research to determine the risk factors – the elements that cause or contribute to an incident – that identify areas for developing and implementing intervention strategies. In trucking, the identified risk factors relate to truck drivers, other drivers, vehicles, fleet and management characteristics, and the physical environment. Current interventions and those under development attempt to target and mitigate one or more risk factors. Interventions can address driver training, education, physical fitness programs, and by acceptance and appropriate use of the new technologies individually or some combination.

Truck Driver Factors

A number of risk factors are associated with truck drivers. In the preliminary evaluation from the Large Truck Crash Causation Study fatigue, speeding, distraction/inattention, aggressive driving, and motor carrier dispatching were found to be primary reasons for 286 of 1000 crashes (NHTSA, 2002; Craft and Blower, 2004). The critical event was attributed to the truck driver actions in 29%, of two vehicle crashes; other driver reasons included non-performance, recognition errors, and decision errors. Driver decision errors were most common in single truck crashes. Surveys of commercial motor vehicle (CMV) fleet safety managers and experts in motor carrier safety conducted by the Commercial Truck and Bus Safety Synthesis Program identified insufficient driver training, risk taking behaviors, fatigue, driver health and wellness, and driver turnover as important risk factors (Knipling, 2003).

Lack of seat belt usage has been identified as an important risk factor for drivers. The "Safety Belt Usage by Commercial Motor Vehicle (CMV) Drivers" study observed only 48% of the drivers of 3,909 trucks at 117 sites in 12 states using seat belts (FMCSA, 2003). Usage rate for units identified as a major regional or national fleet was 55% but only 44% for trucks that were either independent or part of local fleets. The highest usage rate was found in single tankers (61%), and the lowest usage was found in single-trailer dump truck (26%). Subsequently an industry partnership to encourage seat belt use by commercial drivers has been formed by FMCSA, the National Private Truck Council (NPTC), Owner-Operator Independent Drivers Association (OOIDA), American Trucking Associations (ATA), the Motor Freight Carriers Association (MFCA) and others.

Fatigue has long been recognized as a risk factor in truck crashes. A 1990 study of 182 heavy truck crashes involving truck driver fatalities identified the most frequently cited probable cause as fatigue, with a 31% incidence (NTSB, 1990). Fatigue was found to be a related factor for at least one truck driver in 1.6.7% of 3,169 fatal accidents involving 3,311 heavy trucks (NTSB, 1995). The NTSB suggested that driver fatigue was underestimated by Fatality Analysis Reporting System (FARS) data in general and specifically with regard to truck drivers. Further, truck driver fatigue may be a contributing factor in 30% to 40% of heavy truck accidents (NTSB, 2002).

Drivers may face a trade-off between rest and driving schedules. Using physiological and self-reported measures from 188 commercial drivers, Filiatrault found a significant correlation between sleep quality and schedule based priorities. Drivers' attitude toward maintaining a schedule versus insuring proper rest was the most important predictor of sleep quality (Filiatrault, 2002).

FMCSA TechBriefs summarize studies of matters such as sleep schedules, stress, fatigue, alertness, and driver wellness training. One brief reported on a study comparing drivers in two tractor trailers equipped to monitor the driver's face, driving performance, sleeper berth environmental conditions, and subjective driver alertness ratings. It concluded that road and travel disturbances detrimentally affected the quality of sleep of truck drivers, particularly of those driving in teams (Carroll, 2002).

Long haul commercial drivers who are obese or who have sleep-related breathing disorders may be at higher risk for traffic accidents. A study of 90 commercial long-haul truck drivers 20-64 years of age found that drivers identified with sleep-disordered breathing had a two-fold higher accident rate per mile than drivers without sleep-disordered breathing. Obese drivers presented a two-fold higher accident rate than non-obese drivers (Stoohs et al., 1994). A subsequent study reported that drivers with sleep apnea perform as poorly as persons who are legally intoxicated (Alvarez, 2002).

A study of 593 randomly selected long-distance truck drivers interviewed with regard to their typical work and rest patterns at public and private rest areas indicated that almost one-half reported falling asleep while driving a truck and one-fourth had fallen asleep at the wheel in the past year. Factor analysis identified greater daytime sleepiness; more arduous schedules; older drivers; poorer sleep on road; symptoms of sleep disorder; and a greater tendency to night-time drowsy driving as predictive factors. Interventions that limited work hours, enabled drivers to get sufficient rest, and identified drivers with sleep disorders were suggested to reduce the likelihood that drivers would fall asleep while driving (McCartt et al., 2000).

Finally, the Trucks Involved in Fatal Accidents Report for 2000 (TIFA) reported 2% of truck drivers as drowsy or asleep. However, driving too fast (7.6%), ran off the road (6.9%), and inattention were the most common truck driver factors reported. Only 2.2% had been drinking alcohol before a fatal crash, and drug use was less than 1%. Almost two-thirds of incidents reported no driver factors (Matteson, 2001).

Other Drivers

Drivers of other vehicles are frequently responsible for crashes involving large trucks. The Automobile Association of America Foundation reported that in 80% of passenger car-truck crashes with passenger car fatalities, the car driver was driving dangerously. Of 94 factors identified with crashes, only 27% of truck drivers had at least one unsafe driving act (AAA Foundation for Traffic Safety, 2002). A preliminary evaluation of 286 of 1,000 crash investigations from the Large Truck Crash Causation Study indicated that, for two vehicle crashes, the critical event was attributed to the truck driver actions in only 29%, of crashes, compared with 60% to the actions of the other vehicle driver (Craft, 2004).

A study of unsafe driving acts (UDAs) by motorists driving near large trucks found common UDAs included tailgating, speeding, and driver distraction and less common factors including failure to obey traffic controls, reckless driving, driving into opposing traffic, and disregard for poor weather or visibility conditions (Stuster, 1999; Office of Motor Carriers, 1999). A report of heavy truck collisions from Kentucky found that the most common cause of a car-truck incident was another vehicle crossing the centerline or turning into the path of a truck – accounting for about one-third of crashes (Pigman, 1999). Matteson reported similar findings; the other vehicle crossed the center-line and hit the truck head on in about 10% of fatal collisions (Matteson, 2003).

To address the risk factors associated with drivers of other vehicles, the FMCSA suggests that drivers of other vehicles need to be educated on how to share the road with commercial trucks. *Share the Road Safely* Program and web site of FMCSA is intended to improve the knowledge of all highway users in order to reduce the likelihood of a crash with a large truck, and to minimize the consequences of those that do occur.

Vehicle Factors

In addition to driver behaviors, the type, number and interaction of vehicles are important to understanding the causes of trucking incidents. Eighty-four percent of the large trucks in fatal crashes are in multiple vehicle crashes, compared with only 61% of passenger vehicles. Only 5% of large truck occupant fatalities, and 11% of large truck occupant injuries, occur in multiple vehicle crashes (NHTSA, 2004). Of fatal crashes involving large trucks, nearly 77% involved a collision with another vehicle compared with only 5% involving a rollover (FMCSA, 2003). In two-vehicle fatal crashes involving a large truck and another type of vehicle, both vehicles were impacted in the front 29% of the time, suggesting head-on collisions. Trucks were impacted from the rear almost twice as often as other vehicles, 16% compared with 7% (NHTSA, 2002).

Fleet Factors

Fleet factors also influence safety performance in the trucking industry. The TIFA 2000 study indicated that 49.1% of the trucks in fatal crashes were driven by for-hire interstate carriers, nearly one-fifth by privately owned interstate carriers. Only 17% were privately owned intrastate carriers. About one-third were on local haul trips within 50 miles of their home base (Matteson, 2001).

The FMCSA conducted a study of safety performance by trucking industry segments using 1992 to 1998 data from the Motor Carrier Management Information System (MCMIS) and the Motor Carrier Safety Status Measurement System (SafeStat). The performance of 11 for-hire and 10 private commodity segments was evaluated on nine standard safety measures related to driver performance, vehicle scores, accident history, crash rates, and safety management. The passenger segment and the less-than-truckload segment were the safest of the for-hire segments, while refrigerated foods and produce segments were least safe. Among private commodity carriers, the safest groups were the tank and household goods transporters, while general freight and large machinery segments had lower safety ratings. Overall, private commodity carriers displayed significantly safer ratings than those carriers in the for-hire segments (FMCSA, 2002). Although studies have demonstrated that fleet factors influence safety performance, little is known of the underlying reasons for such influence.

Physical Environmental Factors

Environmental conditions also contribute to the safety and health experience of trucking. The frequency of fatal crashes involving trucks varied by time of day and year, as well as by weather conditions. There is seasonal variation with most fatal crashes occurring in June, and the fewest in April. About two-thirds occurred in rural areas, the same proportion occurred in daylight. More than 80% took place on dry roads, and in normal weather conditions (Matteson, 2003).

Availability of space to rest is important, particularly with increasing truck traffic. In a study of more than 2,000 truck drivers from Canada and the U.S., drivers indicated that they decide where they will park and make that decision while driving. Safety, convenience and the availability of basic amenities were listed as important considerations. Drivers preferred well-lighted lots to the presence of security personnel for safety. Drivers favored rest areas for short stops. A universal comment from drivers was the need for more spaces (Chen et al., 2002).

Management Practices

Management practices are another area that affect driver safety behavior. Management support is critical in developing a positive safety culture, management practices can also compel drivers to push themselves physically and mentally with consequent adverse effects.

Arboleda's (2003) study of management practices at 116 trucking firms found that strong safety cultures resulted in fewer incidents. Using data on perceptions of safety training, driver autonomy, opportunity for input, and management commitment collected from drivers, dispatchers, and safety directors, the study found that driver scheduling autonomy was not a predictor of a positive safety culture but that driver fatigue training and driver opportunity for safety input were significant predictors for safety. Top management commitment to safety was a significant predictor for all three occupation groups; the effect on drivers was strongest.

Effective Commercial Truck and Bus Safety Management Techniques (Knipling, 2003), part of the FMCSA's *Commercial Truck and Bus Safety Synthesis* documents addressed 20 distinct safety problems such as driver knowledge of safety and behaviors and vehicle maintenance, and 28 management methods, including driver certification, evaluation and recruiting, and scheduling. Based on a review of literature, interviews with industry experts, and suggestions from the TRB Synthesis Panel, Knipling concludes that effective safety management results from multiple factors, and that more rigorous evaluation studies to improve qualitative and quantitative risk factor knowledge are needed.

Prevention and Control (Intervention)

Prevention and control (intervention) strategies are developed using the findings from surveillance and analytic research steps of the Public Health Model.

Intervention efforts generally target the subsystems: 1) behavioral (driver), 2) physical, (vehicle) or 3) managerial/work organization subsystems. Interventions are typically most effective when they address multiple subsystems. Prevention and control of occupational injury and illness requires a multi-dimensional approach applying the principles of disciplines including data management, economics, education, engineering, and psychology. The complexity of intervention strategies in trucking is best understood through examples.

Behavioral – Driver Factors

Although intervention strategies intended to influence behavior include pre- and post-employee selection, and disciplinary controls, the trucking industry has focused on driver training. Training is used to modify behavior to lessen the occurrence of undesirable driving actions such as speeding and aggressive driving, and to reduce the number of fatal and nonfatal incidents. Factors that can be addressed in training include vehicle maneuvering and control, operation in adverse conditions, operation under fatigued conditions, and avoiding negative health outcomes.

Historically the Federal government has not regulated driver training. The Federal Highway Administration developed a *Model Curriculum for Training Tractor-Trailer Drivers* (1985, GPO Stock No. 050–001–00293–1), which incorporated recommendations for training standards for CMV drivers including minimum training guidelines, specifications for vehicles and facilities, instructor hiring practices, and graduation information, but use of the curriculum was discretionary. A later study mandated by the Intermodal Surface Transportation Efficiency Act (ISTEA) found private sector training of entry-level drivers in the heavy truck, motor coach, and school bus industries was inadequate. In 1991 Congress required Federal entry-level training requirements be established for CMV drivers. The positive effect of commercial drivers licensing (CDL) on trucking safety inclined the FMSCA to take a basic licensing approach to improve safety performance. The current Federal and State CDL license programs do not however mandate training to obtain a license.

Although there are differing views on when and who to train, and the effectiveness of training, the FMCSA initiated federal regulation of CMV driver training in May 2004 by issuing a final rule establishing "Minimum Training Requirements for Entry-Level Commercial Motor Vehicle Operators." An entry-level driver is defined as "a person with less than two years experience operating a CMV that required a CDL." The rules apply to drivers in the heavy truck, motor-coach, and school bus industries, and those in interstate commerce. The agency also proposed training topics be expanded in traditional CDL requirements covering subjects such as medical qualifications; substance abuse; driver well-being; and whistleblower protection.

Although entry-level training is usually accepted as improving safety, the measured effects are too desperate to dependably predict the effect of training programs or of the new requirements. For example, case studies suggest that driver training programs reduced truck related incidents, but the results vary drastically, ranging from 2 to 40 percent. FMCSA's a preliminary regulatory economic evaluation, which considered the costs of medical and emergency services, property damage, lost productivity, as well estimates of pain, suffering, and quality of life-losses determined that the new training rules would have to reduce truck related crashes by entry level drivers by 5 percent – 201 crashes – annually to be cost beneficial (*Costs of Large Truck- and Bus-Involved Crashes*, (Zaloshnja et al., 2000 and 2004). Because the effects of training programs on safety performance are not certain, not all critics agree that training programs or the new rules will be effective safety interventions.

Commercial driver training programs of varying costs and duration are available from trucking firms, specialized providers and community colleges. The courses are structured to meet the requirements to obtain the CDL. Traditional methods combine textbooks, classroom and hands-on training. Emerging information technologies have expanded training modalities to include driving simulation, computer and internet based instruction and self-paced instructional videos.

Several public-private partnerships involving the FMCSA, the American Trucking Associations (ATA), the American Trucking Associations Foundation (ATAF) and the National Private Truck Council (NPTC) have served to develop driver education programs addressing driver fatigue, wellness, health, and fitness. The *Awake at the Wheel* program included public service announcements, brochures and a video on the alert driver. It also provided a 4-hour train-the trainer course, and a 1 to 3 hour course for trucking executives. The *Gettin' in Gear* Program was intended for commercial vehicle drivers, their employers and their families. The program emphasizes the importance of driver health to safe driving; highway safety; and preserving the workforce. It addresses the numerous health risks affecting commercial drivers, including smoking, obesity, and poor dietary habits, and overall fitness and encourages adopting a healthier lifestyle (Krueger, 2002).

Countries differ in their approaches to training. In both Canada and the U.S., the employer is responsible for evaluating drivers and determining their training needs, and is at liberty to decide the specifics of any training. Training is available from a variety of sources; there is no universal accreditation to standardize and evaluate the effectiveness of training programs. In contrast, European programs are regulated by the European Agreement concerning the International Carriage of Dangerous Goods by Road; programs must be certificated and accredited. Countries verify programs differently; for example, the Netherlands requires examination of those attending training while Sweden has standards for accreditation that individual training companies must adhere to during business conduct (Kuncyte et al., 2003).

Training in simulators is safer and generally less expensive than behind-the-wheel training. Simulators can present trainees with crisis situations, such as a pedestrian entering the roadway in front of the vehicle, which are difficult to recreate in with real trucks. Simulators however provide a less realistic experience with loss of vehicle control and recovery than training programs using full size trucks with stabilizers on skid pads. The degree of realism varies by system. Some simulators mount truck cabs to re-create the motions, noises, and actions of driving with 180 degree virtual reality scenarios. Others are little more than a simulated steering wheel and gear-shift with a simple computerized display. Intuitively, more elaborate simulators provide more effective training, but elaborate simulators are costly to use and mainly reserved for research.

Drivers of vehicles that may be in proximity to large trucks in traffic also need education to appreciate the realities of trucks with large mass, heavy loads, and limitations on maneuverability. There have been campaigns to publicize the *No-Zone*, area behind large trucks that other vehicles cannot safely enter.

Selection of employees using defined work characteristics or later screening of unsafe drivers may also serve to improve safety performance. In the trucking industry, the CDL, which establishes baseline standards for operators of large commercial vehicles, serves as both an ex-ante and ex-post selection mechanism. Minimum standards are established by the FMCSA (http://www.fmcsa.dot.gov/rulesregs/fmcsr/regs/383.htm) but CDLs are issued by the states according to Federal regulations that govern the State programs. CDLs are required for vehicles weighing 10,001 pounds gross vehicle weight rating (GVWR) or more. Operators may be subject to other business regulations or regulations for hauling hazardous waste.

The physical qualifications of commercial motor vehicle drivers are also regulated by the Federal government. For example, Title 49 CFR Part 391.41 stipulates physical, medical and psychiatric disorders including a loss of extremity that would interfere with driving, diabetes under treatment with insulin or current alcoholism, and conditions such as epilepsy, that disqualify an individual from operating a CMW. Vision and hearing must also meet specified standards (NTSB, 2002).

Physical – Vehicle Factors

Changes in the physical work environment may also improve safety and health. This section will focus on electronic interventions that have evolved during the Age of Information. In general these interventions are intended to provide a more comfortable environment and information useful in operating the vehicle. The latter may include information about the status and performance of the vehicle systems. However, the same technologies may result in complex and distracting array of visual and audible information about the vehicle and roadway.

The Department of Transportation's Intelligent Vehicle Initiative (IVI) provides valuable insight into the types and benefits of these electronic interventions. Established in 1998, the IVI is intended to prevent driver distraction, and facilitate the development and deployment of crash-avoidance systems (Resendes, 2003). The IVI focuses on improving driver activity related to safety performance under normal conditions, degraded driving conditions, and imminent crash conditions for several types of vehicles. The IVI addresses four areas related to collision avoidance – from the rear, during lane changes or merges, during road departure, or at intersections and two areas related to the driver – enhancing vision, and providing the driver with condition warnings. Field tests of a rear-end Collision Warning System (CWS) that includes Adaptive Cruise Control and Advanced Cruise Control are underway on 100 new commercial trucks.

Preliminary results indicate positive results, particularly in driver acceptance of the device. In another study, the viability of electronically controlled braking systems is also being explored (Resendes, 2003). The United States Department of Transportation's Joint Program Office (JPO) for Intelligent Transportation Systems (ITS) has been actively collecting information regarding the impact of ITS projects on the surface transportation network and on ITS costs since 1994. The resulting database provides estimates of ITS costs to be used for policy analyses, benefit/cost analyses, and project planning. The range of applications extends from advanced traffic control systems to ramp meters, to CWS. Technologies are rated in terms of the impact on safety, mobility, customer satisfaction, productivity, and impact on energy and environment. A recent report has compared the relative benefits and costs of Intelligent Transportation Systems as of 2003 (Maccubin, 2003). The most recent annual summary of benefits by program area and by benefit measure is available at: http://www.benefitcost.its.dot.gov.

There are a number of safety information technologies in use inside vehicles that provide immediate feedback to the driver or store information for later review. These on-board devices are in contrast to the more common warning devices placed outside the vehicle, such as stationary intersection alerts. Some devices, for example the CWS, are in limited use and also are being evaluated in field operational trials. Although some of these technologies were developed for other purposes, they have the potential to improve vehicle safety. Definitive quantitative data regarding their effects on preventing collisions are generally not publicly available.

CWS for commercial vehicles are usually radar-based devices located on the front or sides of commercial vehicles. They emit an audible or visible signal as other vehicles or objects are being approached and speed drivers' response to an imminent collision. They may also distract drivers or affect team drivers' ability to get berth-sleep. Trucking trade journals suggest that CWS are effective in preventing or mitigating collisions. In 2000, a manufacturer of CWS released a summary of three years of data from an evaluation study that indicated an 80% reduction in collisions. Six of eight fleets reported 100% reductions, one fleet reduced lane change and rear-end collisions from 0.33 per million vehicle miles traveled to zero. Other fleets also reported substantial reductions in fixed object collisions, and lane change and rear-end collisions (Roadranger, 2000). CWS may be used in combination with technologies such as antilock braking systems (ABS), Adaptive Cruise Control, and various information storage devices. Information collected during the use of such systems can be used in driver education, evaluation of driving patterns, or crash reconstruction. A survey of truck drivers' attitudes toward feedback by technology found that CWS was among the most frequently mentioned technologies (Roetting, 2003).

Global Positioning Systems (GPS) devices can accurately determine and provide information on vehicle location. This is useful to the driver in navigating, and can be used by dispatchers to track driver movements. The use of this technology by emergency responders to located accidents has shortened their response time, a potential critical element in victim survival. GPS can also be used to locate stolen vehicles or vehicles that have deviated from a projected route. GPS might also be used to track vehicles with hazardous materials in a security crisis.

Event Data Recorders and feedback systems are electronic devices that monitor and record events such as hard-braking incidents that may reflect driver behavior. Similar to CWS, Event Data Recorders may be used in combination with devices such as Adaptive Cruise Controls. Data collected may be used in reconstructing a crash and determining the contributions to cause (NHTSA, 2002).

Other technologies such as Fatigue Tracking Systems are currently being tested for commercial use. One device measures the percent of driver eye closure time. These systems could be used to provide a warning to drivers, or slow or control the vehicle. These devices are undergoing tests and their effectiveness is not established.

Some fleets are installing speed control devices on trucks to ensure that drivers remain within a prescribed speed. Speed control devices are unpopular with drivers as they limit the driver's ability to accelerate to pass another vehicle or to avert a collision. Their impact on safety will not be clear until there is more experience with these devices.

Cell phones and other communication devices are controversial. Studies of cell phone use suggest that they may be a major distraction if not a potential driving hazard. A review of nine studies that suggested mobile communications can increase the risk of collisions by causing delayed reactions. "Drivers using cell phones were found to have braking reaction time three times longer than drivers under the influence of alcohol, and a four-fold increase in risk compared to not using a cell phone." http://www.occupationalhazards.com/articles/12035. Responding to the perception of cell phone hazards, the City Council of Washington D.C. passed an ordinance in 2004 which made any vehicle driver, including truck drivers, using a cellular phone without a hands-free device subject to a fine of $100.00 and 1 point. Exxon Mobil Corporation banned cell phone use by drivers while working in June 2004. In spite of any risk associated with hand-on cell phone usage, the cell phone is of positive value to truckers in finding rest stops, arranging schedules, and communicating road problems. Like many technologies, the benefits are substantial when properly used.

Managerial or Work Organization

Managers, regulators and customers of the trucking industry affect safety and health through their control of work organization. Trucking managers can play a central role in creating a culture in which safety is a priority for drivers through personal contact, incentives, training, and by sanctioning unsafe acts. For example, the Owner-Operator Independent Drivers Association has sponsored campaigns, such as the Safe Driver Awards Program, encouraging individual members to drive safely (OOIDA, 2003). However, the tension between scheduling for profitability and promotion of safe practices creates ambiguity in mangers role in the safety process. Management practices can reduce driver fatigue, and improve safety, but may also force drivers to push themselves physically and mentally with adverse effects. Drivers respond to pressure from dispatchers to continue driving, even when aware of their own fatigue (Filiatrault, 2002). Scheduling may limit driver's ability to recover from fatigue. Focus groups of industry representatives assembled by the FHWA suggested that shipper and motor carrier personnel are unaware or unconcerned about pressures on drivers. Firms accept unrealistic deadlines to obtain business and then pressures drivers to exceed Hours of Service (HOS) limits and safe speeds as well as inappropriately load or unload freight to make timely deliveries. Dispatchers were crucial in any effort to reduce fatigue as they are directly involved in setting schedules. Managers have leverage to improve safety by enforcing existing regulations. Fleet managers can ensure that drivers have credentials for their vehicle. Despite revisions of the CDL to incorporate data on driving violations, 8% of commercial drivers of large trucks in fatal crashes had no CDL, only 86% had a valid CDL and of these, only 92% had a CDL for the class of vehicle they were driving (FMCSA, 2002).

Managerial support for the HOS of the Federal Motor Carriers Safety Administration might also improve safety and reduce fatigue. The legislative and administrative history of the HOS regulations is given extensive discussion in the chapter on regulation in this volume; we limit ourselves to a brief summary of the recent changes and the safety issues raised by these changes. The regulations in force from 1962 until 2004 established an 18 to 23 hour work schedule with 10 hours driving and up to 5 hours of non-driving work before a mandatory 8 hours rest. Drivers could extend the length time over which work could be done by inserting non-working time breaks into this schedule. Drivers were also limited to 60 hours of work in seven days and 70 hours in eight days.

In order to provide drivers with necessary rest and sleep within the realities of commercial driving, the FMCSA promulgated new HOS rules in April 2003 with a compliance date of January 4, 2004. The revisions are estimated to prevent between 24 and 75 driver deaths per year, prevent over 1,300 fatigue related injuries and 6,900 damage only crashes, with a national annual savings of $628 million.

The new rules create a 21 hour drive-rest cycle. Drivers of property-carrying CMVs may not drive for more than 11 hours after 10 consecutive hours off duty, or for any period of time after having been "on duty" 14 hours following 10 consecutive hours off duty. Non-driving and break time is, with few exceptions, counted against the 14 hours, resulting in a hard shut down 14 hours after a driver starts to work without regards to the nature of the driver's activities. If drivers use a sleeper berth required off-duty hours may be divided into 2 periods, neither of which may be less than 2 hours. The new regulations retained the 60 and 70 hour rules but allow drivers to begin a new 7- and 8-day cycle after they have been off duty for 34 consecutive hours. Drivers are still required to maintain duty logs for each 24-hour period but those who are out of compliance will now be declared out of service until they go off duty for the required number of hours.

Although the revised HOS regulations may be a positive direction for improving safety, on July 16, 2004, the U.S. Court of Appeals in Washington, D.C. rejected the new HOS rules and sent them back to the FMCSA for reconsideration. The court indicated concerns with several aspects of the regulation, but its central concern was the failure of the agency to consider "the statutorily mandated factor of drivers' health in the slightest." The court raised specific concerns about the effects of vibration, noise, and the 11^{th} hour of driving. The unknown effect of restarting the weekly log after 34 hours off duty, the ability of drivers to split the required 10 hours off duty into shorter periods if using a sleeper berth, and the failure of the FMCSA to mandate the use of electronic on-board recorders (EOBR) to monitor compliance were also raised. The court mandated a limited period of consideration, the new hours-of-service rules remain in effect through this period. Issues surrounding HOS have stimulated new research but it is unlikely that much new information regarding driver health that can be obtained in the time available.

Driver fatigue appears to be influenced by fatigue inducing factors and management safety practices. To reduce fatigue and the occurrence of incidents, research suggests management practices such as encouraging a safer environment, designing manageable schedules and shifts, and assisting drivers with tiring tasks (Morrow, 2004). Training drivers to recognize fatigue is a marker of a strong fleet safety culture for employees (Arboleda, 2003). Managers have the opportunity to create a safety conscious culture and to lead by example. If safety is perceived to be a priority by management, drivers will be more likely to drive safely.

Discussion

The term Age of Information has many possible interpretations and implications as it applies to trucking. It refers not just to the exponential explosion in the amount and quality of data available, but to the recent technologies that make it possible to store, screen, integrate, interpret, access, and utilize information for operations of single vehicles and fleets. While empowering truck owners and drivers with tools for managing and driving their vehicles, information has also made the task of managing vehicles more complex. Because of this, the commercial drivers and vehicles in the context of information should be viewed as complex interactive systems operating in a complex external environment.

There are numerous levels or layers of information. One level of information involves cumulative epidemiological statistics on large truck crashes that have been consistent in highlighting this problem over many years. Data on truck crashes, costs, and possible interventions inform regulatory decisions such as Hours of Service rules or rules regulating training for entry level drivers. A relatively new development is the sharing of information between primary sources – public health and transportation agencies – to better manage trucking safety (TRB 2004). Data on individual drivers are potentially available through CDL records, state police crash records, and other sources. Individual companies maintain detailed fleet data, including records on specific vehicles.

In addition to the fundamental economic importance of commercial trucking, the important public health implications of commercial trucking are well known and thoroughly documented in published national statistics. Numerous fatalities, injuries, and damages result from crashes involving large trucks that extend beyond the trucking industry as they frequently involve drivers of other vehicles and their vehicles.

Although truck safety information is available from the numerous sources described in this chapter and others, no single source or combination of sources permit accurate calculations of risk. One problem in estimation of risk is that good denominator metrics relating truck and driver exposure to adverse outcomes are lacking. Various surrogate indices, such as million-miles traveled, offer crude substitutes for true exposure measures.

Many of the risk factors which influence the occurrence of crashes are relatively well known. Some of these are environmental factors, such as road conditions, weather, time of day, and visibility. Other factors relate to the physical configuration and condition of vehicles. Human risk factors clearly play an important role as well. Some of these relate to truck drivers, while factors influencing drivers of other vehicles are also important. Again, there is a scarcity of quantitative information on the contributions of these factors. Studies such as the Large Truck Crash Causation Study conducted by the National Highway Traffic Safety Administration will do much to clarify these risk-related issues.

Interventions are not always well defined and many are in the trial or evaluation stage. Much of the discussion about training is anecdotal and based on personal experience of safety personnel. The numerous commercial training courses available focus on preparing the driver to understand and competently drive a large truck in most common traffic situations. These courses prepare the driver to obtain a CDL and to find employment. The courses range widely in terms of cost, duration, and content. One commercial company combined classroom training with realistic simulator training in a full-size truck cab, behind the wheel training in a large truck on a slippery skid pad with a rain curtain, and physical fitness training. The program was discontinued, prior to conducting a robust evaluative study.

As recently as May 2004 there is a lack of stakeholder consensus on the effectiveness of driver training programs. In the comments on the FMCSA Final Rule on training for entry level drivers, estimates of crash reduction from driver training ranged from two to 40 percent. The FMCSA justified the rule in terms of cost benefit using various assumptions about crash reduction and also about crash costs.

Despite the lack of agreement regarding the effectiveness as well as the lack of evaluative studies, training has been a prominent intervention in trucking. The lack of evaluative studies can be partly attributed to a number of inherent difficulties in evaluating the effects of driver training on driving performance. One problem is that such evaluations would ideally be conducted prospectively over extended periods of time, preferably years of driving history. Another problem is to relate training to improvements in driving performance, for example, there is difficulty in measuring crashes avoided or prevented. The FMCSA Research and Technology Stakeholder Forums have clearly identified various aspects of driver training as important. However, there is not agreement on when to train, how often, training content, who should train, and how to evaluate training.

Perhaps most impressive in the Age of Information are the technological advances that appear promising to improving the safety and health experience. Electronic transmission of information between driver and dispatcher, between driver and the physical environment, and between driver and the truck are changing how the industry operates. With technology changing rapidly, the safety and health community can expect many new methods to protect the worker and improve productivity.

A number of activities are underway to identify research gaps and needs. These include activities of the Transportation Research Board (TRB) including the Truck and Bus Safety Committee and Task Forces, a National Institute for Occupational Safety and Health's Motor Vehicle Research Program with two projects focusing on commercial truck drivers, and the FMCSA Commercial Truck and Bus Safety Synthesis Program. Over 125 specific research recommendations are outlined in the FMCSA sponsored report on *Results from the Fall 2003 Research and Technology Stakeholder Forums* (FMCSA, 2004). These recommendations fall into the general areas of research related to the Driver, the Vehicle, the Carrier/Shipper, and the Roadside/Environment. Approximately one-fourth of the total research recommendations focused on driver factors, highlighting insurance company statistics that 95% of crashes are related to driver factors and error. The majority of the driver-related research centered on training, seen as the best way to improve driver performance (FMCSA, 2004). This confirms that priorities are being defined, but research on trucking information has a long road ahead.

In summary, there are abundant sources of trucking related information but at present these have not been linked to form a composite overview of trucking health and safety. There are initiatives underway to improve information collection, linkage, and utilization and these advances promise great future accomplishments for trucking health and safety. Also, the evaluation of interventions to improve trucking health and safety is expanding rapidly as of 2005. We are hopeful that these initiatives will improve our knowledge of the factors affecting safety and health in commercial trucking, point the way to more effective interventions and, most important, result in truck driving becoming a safer occupation and improved safety on the public highways.

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