HMCRP

REPORT 7

HAZARDOUS MATERIALS COOPERATIVE RESEARCH PROGRAM

Sponsored by the Pipeline and Hazardous Materials Safety Administration

Role of Human Factors in Preventing Cargo Tank Truck Rollovers

TRANSPORTATION RESEARCH BOARD
OF THE NATIONAL ACADEMIES

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Role of Human Factors in Preventing Cargo Tank Truck Rollovers

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HAZARDOUS MATERIALS COOPERATIVE RESEARCH PROGRAM

The safety, security, and environmental concerns associated with transportation of hazardous materials are growing in number and complexity. Hazardous materials are substances that are flammable, explosive, or toxic or that, if released, produce effects that would threaten human safety, health, the environment, or property. Hazardous materials are moved throughout the country by all modes of freight transportation, including ships, trucks, trains, airplanes, and pipelines.

The private sector and a diverse mix of government agencies at all levels are responsible for controlling the transport of hazardous materials and for ensuring that hazardous cargoes move without incident. This shared goal has spurred the creation of several venues for organizations with related interests to work together in preventing and responding to hazardous materials incidents. The freight transportation and chemical industries; government regulatory and enforcement agencies at the federal and state levels; and local emergency planners and responders routinely share information, resources, and expertise. Nevertheless, there has been a long-standing gap in the system for conducting hazardous materials safety and security research. Industry organizations and government agencies have their own research programs to support their mission needs. Collaborative research to address shared problems takes place occasionally, but mostly occurs on an ad hoc basis.

Acknowledging this gap in 2004, the U.S. DOT Office of Hazardous Materials Safety, the Federal Motor Carrier Safety Administration, the Federal Railroad Administration, and the U.S. Coast Guard pooled their resources for a study. Under the auspices of the Transportation Research Board (TRB), the National Research Council of the National Academies appointed a committee to examine the feasibility of creating a cooperative research program for hazardous materials transportation, similar in concept to the National Cooperative Highway Research Program (NCHRP) and the Transit Cooperative Research Program (TCRP). The committee concluded, in *TRB Special Report 283: Cooperative Research for Hazardous Materials Transportation: Defining the Need, Converging on Solutions,* that the need for cooperative research in this field is significant and growing, and the committee recommended establishing an ongoing program of cooperative research. In 2005, based in part on the findings of that report, the Safe, Accountable, Flexible, Efficient Transportation Equity Act: A Legacy for Users (SAFETEA-LU) authorized the Pipeline and Hazardous Materials Safety Administration (PHMSA) to contract with the National Academy of Sciences to conduct the Hazardous Materials Cooperative Research Program (HMCRP). The HMCRP is intended to complement other U.S. DOT research programs as a stakeholder-driven, problem-solving program, researching real-world, day-to-day operational issues with near- to mid-term time frames.

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NOTICE

The project that is the subject of this report was a part of the Hazardous Materials Cooperative Research Program, conducted by the Transportation Research Board with the approval of the Governing Board of the National Research Council.

The members of the technical panel selected to monitor this project and to review this report were chosen for their special competencies and with regard for appropriate balance. The report was reviewed by the technical panel and accepted for publication according to procedures established and overseen by the Transportation Research Board and approved by the Governing Board of the National Research Council.

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Mr. Chris Stephens of VicRoads (Victoria, Australia) generously provided substantive, concrete discussion of its Heavy Vehicle Rollover Prevention Program, how the program was developed, and what set it apart from other rollover prevention programs. VicRoads provided the Heavy Vehicle Rollover Prevention Kit for use in the trial and also provided a number of DVDs, which were distributed to carriers for their own use.

FOREWORD

By William C. Rogers
Staff Officer
Transportation Research Board

HMCRP Report 7: Role of Human Factors in Preventing Cargo Tank Truck Rollovers analyzes the root causes of the major driver factors contributing to cargo tank truck rollovers and proposes safety, management, and communication practices that can be used to minimize or eliminate driver errors in cargo tank truck operations. The research focuses on three critical areas of practice that can be quickly implemented and will have long-lasting benefits for motor carriers of all sizes across the tank truck industry. These areas of practice, examined through case studies, include (1) rollover-specific driver training and safety programs, with particular attention to a program on heavy vehicle rollover prevention from VicRoads (the state government roads authority in Victoria, Australia), the components of a good overall safety program, and tips for investigating rollovers to prevent their recurrence; (2) the use of behavior management techniques using on-board technology, direct observation (driver ride-along), training, and other tools and methods to manage driver behavior based on a survey of current technology and interviews with operators who demonstrated successful behavior management processes; and (3) the use of fitness-for-duty management practices in fatigue management, general health and wellness, scheduling and dispatching strategies, and distracted driving prevention.

While the cargo tank truck industry has one of the best safety records in the trucking industry, cargo tank truck rollovers remain a concern. In 2007, the Federal Motor Carrier Safety Administration published the *Cargo Tank Roll Stability Study,* which identified four possible approaches to reducing cargo tank truck rollovers: driver training, electronic stability aids, tank truck vehicle design improvement, and highway design improvement. Several major sources of crash data were reviewed, all of which identified "driver error" as the most significant cause of cargo tank truck rollovers. The *Study* categorized the "driver errors" under the "driver training" heading. While training is a key factor, it has been suggested that other factors in the driver's environment could contribute to a rollover, because even experienced drivers have rollovers. To aid in crash reduction, further root cause investigation, coupled with identifying best practices in driver safety, management, and communication practices, could present an efficient approach to reducing driver errors because it can accelerate improvements by eliminating the trial and error process in countermeasure development.

Under HMCRP Project 13, Battelle Memorial Institute was asked to (1) review U.S. cargo tank truck rollover crash experience from 2007–2009 to determine the root causes; (2) identify other direct and indirect influences on drivers that could cause cargo tank truck rollovers; (3) identify other industry and international best practices that could be used to minimize or eliminate driver errors in the cargo tank truck industry; and (4) conduct panel-approved case studies that discuss the applicability, outcomes, benefits, challenges, and implications of applying the selected best practices. The final result is a report that identifies and evaluates examples of the best safety, management, and communication practices that can be used to minimize or eliminate driver errors in the cargo tank truck industry. The report includes tools that can be readily adopted by fleet operators to aid in implementing the practices.

CONTENTS

Note: Many of the photographs, figures, and tables in this report have been converted from color to grayscale for printing. The electronic version of the report (posted on the Web at www.trb.org) retains the color versions.

SUMMARY

Role of Human Factors in Preventing Cargo Tank Truck Rollovers

This research project identifies good practices in safety, management, and communication that can help cargo tank truck fleet operators reduce the likelihood of rollovers. The research takes good practices from both within and outside the industry; they encompass training, hiring, dispatch (e.g., scheduling and journey planning), safety culture, technology, and other operational components.

This report aims to provide tools that operators can implement right away, both to see near-term results and to begin a sustained process. The busy fleet operator reading this report for practical and implementable solutions—and who may be less interested in the technical approach—will find case studies in Chapter 6 geared toward three specific practice areas. A broader discussion of good practices based on the research team's extensive interviews can be found in Chapters 4 and 5. Appendices containing forms useful in the implementation of said practices can be found online at www.TRB.org by searching for HMCRP Report 7.

The identification of common factors is valuable in ensuring that good practices address appropriate behaviors. *HMCRP Report 1: Hazardous Materials Transportation Incident Data for Root Cause Analysis* identifies the appropriate databases for this analysis. A sampling of 407 police accident reports (PARs) from eight states has been reviewed as a further source in identifying root factors. Driver-related causes are leading factors in cargo tank truck rollovers. These causes lead to the unsafe acts that directly lead to rollovers.

Cargo tank truck operators do influence how drivers behave and do influence their state at the time unsafe acts occur or at the time the driver is faced with a threatening situation. For each of the contributing factors identified, operators can exert influence through programs and practices they put in place. These include

- Fitness for duty,
- Health awareness,
- Safety culture,
- Hiring,
- Training,
- Scheduling and dispatch, and
- Operations.

Good practices employed by companies both within and outside of the cargo tank truck industry have been identified through interviews with over 40 participants representing a cross-section of small to large carriers, private and for-hire fleets, senior executives to drivers, domestic and foreign operations, other industries, industry associations, and federal agencies.

Case Studies

Research focuses on three critical practice areas that can be quickly implemented and would have long-lasting benefit to operators of various sizes across the industry. The overarching goal in the selection of areas for case studies is ensuring the applicability of the results—selecting practices that are significant enough to improve cargo tank rollover performance yet simple enough that they can be readily adopted by a broad portion of the industry. Initial surveys, followed by select detailed interviews, have identified some of the keys to successful safety programs that can reduce the likelihood of rollovers.

The focus of the first case study is training and safety programs, with particular attention on the VicRoads (Transportation Department of the State Government of Victoria, Australia) program on rollover prevention. The study also reviews other curricula in the United States to determine the extent to which the VicRoads curriculum and program would need to be modified to be an effective training tool in the United States. Included are useful training elements such as location-based incident mapping, root cause analysis, and a comprehensive rollover program evaluation checklist.

The VicRoads program was tested with audiences of cargo tank truck drivers and safety managers in the United States. First reactions to the material were uniformly positive. The model truck is an excellent interactive tool for demonstrating the principles of physics, especially the effects of a dynamic load. An appreciable number of the participants indicated that the program's video and slide show would be more effective for tank truck drivers if they concentrated specifically on tank trucks rather than on a variety of heavy trucks.

The focus of the second case study is on the behavior management process. The study discusses the functionality and role of on-board technology, direct observation (i.e., ride-along), training, and other tools and methods in managing driver behavior. The study includes a survey of current technology and interviews with operators with demonstrated successful behavior management processes.

The use of on-board computers to monitor the vehicle and the drivers is growing. Although it is more costly, carriers that were interviewed for the case studies use ride-alongs to evaluate and correct driver behavior. Peers, supervisors, or trainers may conduct these ride-alongs using either formal checklists or other observation forms. Observation can also be through electronic measurements of the vehicle's motions, possibly supplemented with video in and out of the cab. Analysis can range from verbal feedback during a check ride to more complicated formulas for assessing behavior. Case Study 1 noted that recurrent training is essential for all; some drivers need coaching for specific behaviors. The process cycles around for continuous improvement.

The focus of the third case study is driver fitness-for-duty management. The study looks closely at four key areas:

1. Fatigue management,
2. General health and wellness,
3. Scheduling and dispatch strategies, and
4. Driver distractions.

Information useful to tank truck operators to better ensure the fitness and readiness of drivers through their shifts is derived from interviews within and outside of the industry, along with reviews of relevant initiatives and programs within and outside of the United States.

Drivers, companies, and families all play important roles in fitness-for-duty. "Good practices" carriers focus on health and wellness of drivers, including nutrition. They also address causes of distraction and fatigue, through education and driver scheduling. Sleep apnea has been identified as a significant cause of driver fatigue.

Conclusions

Driver-related causes are leading factors in cargo tank truck rollovers. These causes lead to the unsafe acts that directly lead to rollovers. The unsafe acts that are most frequently identified through the PAR analysis are

- Driving too fast for conditions,
- Illegal maneuvering or improper turning,
- Inadequate evasive action, and
- Poor directional control.

The most significant areas of potential driver-related contributing factors that lead to these unsafe acts include

- Information gathering,
- Driver state,
- Physiological condition,
- Obesity and health,
- Alcohol or drug involvement, and
- Vehicle control.

Information gathering is identified as the chief contributing factor, accounting for 72% of identified contributing factors. Information gathering includes such characteristics as distraction, poor situational awareness, failure to recognize a hazard, and inadequate visual surveillance—in short, instances of not paying attention. Driver state accounts for 19% of identified contributing factors and includes such characteristics as impairment (i.e., alcohol, drugs, or medications); aggressive behavior; drowsiness; being asleep; or having limited capacity—in short, not being fit for duty or in the proper condition or state of mind at the time of the crash.

A strong safety culture—where "safety is first, period," where all levels of management walk the walk, and where safety is engrained in operational discussions and decisions—is the single best practice. Other key good practices include hiring the right people, effective training and re-training, use of Electronic on-board recorders (EOBRs), and management observations of drivers. Good practices that are not universally adopted include health and wellness programs, a focus on sleeping disorders and fatigue, and recognition of the driver family as a key partner in safety. EOBRs are becoming universal and, at the time of this report, may soon be required by the Federal Motor Carrier Safety Administration (FMCSA). They do not solve all problems, but they can be used as an effective safety aid. On-board technology and ergonomics also serve to further detach the driver, but with less of a feel for the road and perhaps even an over-reliance on safety features.

Recommendations

Carriers and insurance companies hold the most complete set of information for a detailed root cause analysis, but business reasons prohibit their information being released into the public domain. A process that would allow for root causes at an aggregate level to be obtained and that would ensure legal protection and confidentiality to those providing the data is likely the most effective solution to root cause identification.

Many fleet operators have employed good practices that improve their safety and operating performance and reduce rollovers. The industry should continue to focus on sharing programs and practices that can be successfully implemented by medium and small fleets, with particular attention to the lack of dedicated safety and training staffs that may encumber these types of fleets.

Organizations such as National Tank Truck Carriers and American Trucking Associations provide vehicles to share best practices and educate the industry. FMCSA has also made strong contributions to improve safety through education. Programs like VicRoads can be an effective supplement to existing training programs and videos available to the industry. This would best be facilitated by a not-for-profit or industry association.

CHAPTER 1

Introduction

1.1 Background

The objective of HMCRP Project 13, "The Role of Human Factors in Preventing Cargo Tank Truck Rollovers," is to understand root factors and driver influences that are involved in—and good company practices that seek to mitigate—the approximately 1,200 cargo tank truck rollovers that occur each year in the United States. The risks and stakes are high with cargo tank trucks: liquid contents subject the vehicle to higher centrifugal forces than general cargo, leaving the driver with a smaller margin of error. In fact, the dynamics of many incidents are such that the rollover had already begun before the driver was aware. According to data from the Motor Carrier Management Information Survey (2007–2009), approximately 20% of cargo tank trucks that rolled over were placarded for hazardous material, raising the stakes in the event of a rollover.

Fleet operators—both private and for-hire carriers—invest in technology, operations, and drivers to reduce rollover incidents. These drivers tend to be both more experienced and more highly compensated than the industry average (ATRI, 2011), but experience alone cannot be counted upon to effectively manage these risks. Safety training, company culture, constant reinforcement of awareness, vigilance against distractions and fatigue, health and wellness, and involvement of driver families are the key factors in preparing and maintaining drivers for the challenging assignment of driving a cargo tank truck.

This research project identifies good practices in safety, management, and communication—practices that help cargo tank truck fleet operators reduce the likelihood of rollovers. The research also takes good practices (including training, hiring, dispatch, safety culture, technology, and other operational components) from outside the industry that can be applied to achieve this result.

1.2 Scope

The study encompasses driver-related factors in cargo tank truck rollovers. In order to properly assess root factors, however, crash data from a broader population of truck crashes were reviewed. Accidents that were identified as not being contributed to by driver-related factors were not included in the data analysis. In order to properly assess good practices, those practices that apply on a broader safety scale and applicable practices both within and outside of the cargo tank truck industry were reviewed.

1.3 Approach

The objectives of the study are (1) to identify and analyze the root factors of the major driver factors contributing to cargo tank truck rollovers and (2) to determine best safety, management, and communication practices that can be used to minimize or eliminate driver errors in cargo tank truck operations. The project activities were conducted over two phases. The first phase of the study analyzed driver-related root factors, as well as cultural and lifestyle driver influences, in cargo tank truck rollovers using federal crash databases and a sampling of over 400 Police Accident Reports (PARs) from seven states. This activity incorporated interviews with motor carriers, drivers, industry associations, regulatory agencies, and companies in other industries to identify good practices. At the conclusion of the first phase three areas of focus were identified for case studies that address the good practices in place within and outside of the motor carrier industry that can be applied by fleet operators. These Phase II case studies include training and safety programs, behavior management processes, and fitness-for-duty management programs.

Identification of root factors involves the initial review of key databases identified in *HMCRP Report 1: Hazardous Materials Transportation Incident Data for Root Cause Analysis.* The databases are

- Trucks Involved in Fatal Accidents (TIFA) Survey Fact book, maintained by Federal Motor Carrier Safety Administration (FMCSA) and the University of Michigan Transportation Research Institute (UMTRI);

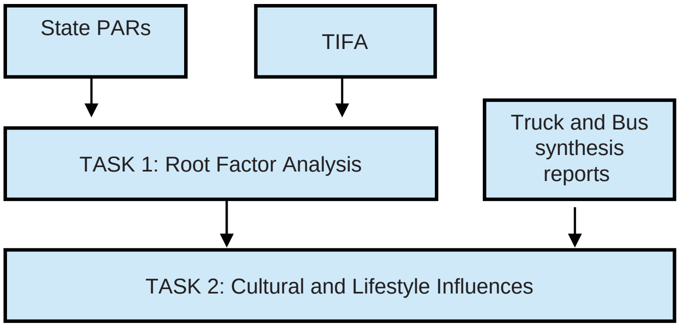

Figure 1. Tasks 1 and 2 research approach to identify root factors and influences.

- Hazardous Materials Information Resource System (HMIRS), maintained by the Pipeline and Hazardous Material Safety Administration (PHMSA); and
- Motor Carrier Management Information System (MCMIS), also maintained by FMCSA.

MCMIS and HMIRS are used to identify a sampling of over 400 PARs, as the elements in these databases are insufficient for the root factor analysis needed for this research. Seven states have provided PARs that, while varied in the depth and richness of data, provide sufficient detail to identify most likely driver-related root factors. The TIFA database contains sufficient detail for analysis of root factors. Commercial Truck and Bus Safety Synthesis Program (CTBSSP) reports provide additional information that aid in the determination of cultural and lifestyle influences. Figure 1 describes the research approach of Tasks 1 and 2.

The next tasks identify good practices employed by companies both within and outside of the cargo tank truck industry. These companies have been identified with the help of the National Tank Truck Carriers Association, American Transportation Research Institute (ATRI), and input from other prominent industry professionals and experts. The research team compiled interview guides intended to help gather responses in a consistent manner for effective evaluation, while at the same time being structured to allow the interviewer to probe as key practices were identified. All interviews have been conducted by senior research staff, enabling a rich dialogue in each of the over 40 interviews conducted. Participants range from small to large carriers; private and for-hire fleets; senior executives to drivers; domestic as well as foreign operations; other industries (including mining, barge, rail, and utilities); industry associations; and federal regulatory agencies. Initial interviews also led to the identification of further interview candidates.

Interviews were analyzed to determine the prominent good practices among the survey group. The factors and influences identified in Tasks 1 and 2 were incorporated into the analysis to ensure that the practices addressed critical driver-related factors in rollovers. The research team considered a number of practices for further case study research.

In Phase II of the project, case studies were selected for three critical practice areas that could be quickly implemented and have long-lasting impact on operators of various sizes across the industry. The overarching goal in the selection was to ensure the applicability of the results—selecting practices that are significant enough to improve cargo tank rollover performance yet simple enough that they can be readily adopted by a broad portion of the industry. These three case studies are based upon programs and practices in place both within the industry and in other industries where operator safety is of paramount concern. Interviews, focus groups, and surveys of existing relevant technology and research are combined to first describe the current state and then to make practical recommendations on how these practices can be implemented. Appropriate tools, such as diagrams and checklists, are provided.

The focus of the first case study is training and safety programs, with particular attention on a VicRoads (Transportation Department of the State Government of Victoria, Australia) program on rollover prevention. The study also reviews other curricula in the United States to determine the extent to which the VicRoads curriculum and program would need to be modified to be an effective training tool in the United States. Useful training elements such as location-based incident mapping, root cause analysis, and a comprehensive rollover program evaluation checklist are also included.

The focus of the second case study is on behavior management processes. The study assesses the role of on-board technology, direct observation (i.e., ride-along), training, and other tools and methods in managing driver behavior. The study includes a survey of current technology and interviews with operators with demonstrated successful behavior management processes. The study provides useful information for operators to implement processes in their companies.

The focus of the third case study is on driver fitness-for-duty management programs. The study looks closely at four key areas:

1. Fatigue management,
2. General health and wellness,
3. Understanding the effects of off-duty activities and schedule, and
4. Awareness of distractions that can affect the driver's state of mind.

Information useful to tank truck operators to better ensure the fitness and readiness of drivers through their shift is derived from interviews within and outside of the cargo tank truck industry, along with reviews of relevant initiatives and programs within and outside of the United States.

CHAPTER 2

Root Causes of Cargo Tank Truck Rollovers

The study of the causes of prior cargo tank truck rollovers established a framework to support the later activities in this project. Given the number of heavy truck rollover crashes expected for the 2007–2009 timeframe, the standard detailed-level root cause analysis is unfeasible. At a more practical level, typical crash data reports lack the level of detail normally required to provide clear answers about the full range of causal relationships. For these reasons, our basic approach is to conduct a higher-level survey of rollover crashes with the objective of defining the broader problem space that can be used to identify and evaluate best practices in the cargo tank truck industry. For comparison purposes, non-cargo tank truck rollover crashes are also studied. The approach was segmented into four activities:

1. Identify crash data set,
2. Develop analysis framework,
3. Conduct root factor analysis, and
4. Summarize findings from root factor analysis.

2.1 The Crash Data Set

The first activity in Task 1 is to identify crash data sets for driver-related root factor evaluation. The research team has reviewed U.S. cargo tank truck rollover crash data from a variety of sources to identify potential driver-related root factors. The research includes a review of *HMCRP Report 1: Hazardous Materials Transportation Incident Data for Root Cause Analysis,* and a detailed review of the key databases identified in that report: TIFA, HMIRS, and MCMIS. Using those databases, the team identified 400 individual cargo tank truck rollover crashes worthy of review and examined PARs for them.

The MCMIS and HMIRS databases did not contain a level of detail sufficient to perform an effective analysis of driver-related factors. The TIFA database, while containing good data, did not have data on a sufficient number of cargo tank truck rollover incidents to stand alone as the project's data source for root factors. To gain sufficient knowledge about driver-related factors, the research team adopted a revised approach to identify additional sources of information. The combined Tasks 1 and 2 approach is shown in Figure 1 (see Chapter 1).

The project team sought incident analyses from large tank truck carriers. In some cases, carriers perform a true root cause analysis, delving much more deeply into the events leading up to an incident and the reasons than do the crash databases. (TIFA is unique in that researchers contact persons involved for extra detail including, for example, the results of drug tests and not simply that a drug test was performed.) Internal carrier information is sensitive, however, and arrangements to access this data source could not be made.

2.1.1 TIFA—Trucks Involved in Fatal Accidents

TIFA is maintained by UMTRI for FMCSA. It is a census file on the fatal accident experience of medium and heavy trucks nationwide and is essential to any evaluation of truck safety issues. The database compilation begins from the files in the Fatality Analysis Reporting System (FARS) database. Information on any fatal truck accident in FARS is extracted and then enhanced by UMTRI by calling the carriers, medical institutions, and law enforcement organizations to confirm information reported in FARS and in PARs generated as a result of the accident. UMTRI extensively supplements the information obtained from FARS using additional fields in the TIFA database. TIFA is the only accident database administered by the government that follows up on the drug and alcohol tests administered and records the results of these tests. While the TIFA identifies only fatal crashes, it is a good source for information to identify potential causes. TIFA provided some indications of driver-related factors that contributed to the fatal crash.

The research team conducted a thorough analysis of crash records in TIFA from 2006 to 2008. While the focus of this assessment is cargo tank truck crashes, which represent a subset of the crashes reported in TIFA, it is useful to analyze a broader set of reports for comparison. Parameters that might contain driver factors were identified and the database was then queried to identify the driver factors at three levels:

1. All fatal truck crashes for four vehicle configurations—trucks with three or more axles, trucks with a trailer, tractors and semitrailers, and doubles;
2. A subset of fatal truck crashes involving cargo tank trucks; and
3. A subset of fatal truck crashes involving cargo tank trucks where a rollover occurred as part of the crash sequence.

The analyses captured 6,570 records overall, with 599 records in the second level and 163 records in the third. The first case was analyzed to provide a set of data that might identify differences between fatal truck crashes and fatal cargo tank truck crashes. Rather than use the entire TIFA dataset for Case 1, by using the subset of vehicle configurations that contain cargo tank trucks, accurate differences might be identified.

2.1.2 HMIRS—Hazardous Material Information Resource System

HMIRS is maintained by PHMSA and covers all reportable hazardous material incidents in the United States as designated in Section 171.16, 49 CFR. Changes to the structure of the HMIRS database in 2005 have made it more difficult to identify rollovers. The database was analyzed for indicators of driver-related contributing factors, but was found unsuitable for that purpose. HMIRS was used to identify hazardous material incidents when combined with the MCMIS database for the purposes of selecting a sample set of PARs.

2.1.3 MCMIS—Motor Carrier Management Information System

MCMIS is maintained by FMCSA and contains information on the safety fitness of commercial motor carriers (truck and bus) and hazardous material shippers subject to Federal Motor Carrier Safety Regulations (FMCSR) and the Hazardous Materials Regulations. MCMIS was felt to be particularly useful to identify rollover events. It contained sufficient fields from which to gather a representative sample of more than 400 incidents involving potential driver-related factors.

2.1.4 PARs—Police Accident Reports

Police reports on over 400 individual rollover crashes were requested from selected state reporting agencies. In order to obtain a thorough sample set of crash incident data, a list was developed to represent operating characteristics (see Table 1).

Table 1. Characteristics used in PAR selection.

Hazardous materials	Region & state
Vehicle configuration	No. vehicles involved
Weather	Trafficway
Accessway	

The PARs were requested from eight states (see Table 2) based upon the database showing sufficient numbers of incidents representing the characteristics in Table 1 and known quality of reporting. All states responded with nearly 100% of the requested records. Some states employed unique codebooks for interpretation of the reports.

2.2 Analysis Framework

An important prerequisite for conducting this type of root cause analysis is to develop a consistent framework for identifying and classifying relevant crash factors. Comparing the available information with an existing framework of crash factors can facilitate identifying the role that each factor may have played in the crash and other contributing factors that logically would have been present, yet may not have been included in the report. The two primary sources of information are the PARs and TIFA. Similar analysis frameworks were developed for each, but are not identical. This has been done intentionally to mine as much information as possible from the separate analyses. Developing a framework that fit both sources would have minimized the result. The amount of detail provided from each of these sources does not allow for identification of corporate and organizational factors.

Table 2. PAR requests from states.

State	Number Requested
Colorado	30
Florida	15
Louisiana	77
New York	53
Oklahoma	50
Pennsylvania	50
Texas	80
Virginia	57
TOTAL	**412**
Received	**407**

The TIFA analysis evaluates several driver-related factors: age, speeding, hours driven prior to accident, overall health, alcohol involvement, drug involvement, avoidance maneuver, violations, and other driver-related factors. Each of these factors will be discussed in the following section.

The conceptual framework for PAR analysis has been developed as a matrix that matches identified unsafe driver acts to contributing factors. Unsafe driver acts include

- Driving too fast for conditions,
- Following too closely,
- Illegal maneuvering or improper turning,
- Failing to signal,
- Inadequate evasive action,
- Panic or freezing,
- Overcompensating,
- Poor directional control,
- Failing to heed, and
- Unknown reason.

Contributing factors and their defining characteristics are shown in Table 3.

Researchers have analyzed 407 PARs against the framework, reviewing both data and narrative fields contained in the reports. The assignment of reports has been overlapped so that the results of each researcher can be compared and reviewed with senior project researchers to ensure consistency of analysis. Likely contributing factors are correlated to the unsafe driver acts based upon the report of the investigating officer. The researchers have sought not to instill their own opinions or guesses on what the contributing factors may have been; rather, they have interpreted and recorded what the officer documented in the report. The PAR analysis focuses on driver behaviors; therefore, for the records in which contributing factors related solely to the vehicle or to the environment (and not to the driver) or in which no clear driver-related contributing factors were identified, the contributing factors are listed as "none specified" in the summary table. If a driver-related factor accompanied a vehicle-related or environment-related factor, then the record is included in the summary table and classified under the appropriate driver-related contributing factor. In all, 26% of the records analyzed have been classified. The remainder could not be classified as the reports did not contain sufficient information to clearly determine factors.

Table 3. Definition of contributing factors in PAR reviews.

Contributing Factors	Defining Characteristics
Personal Factors	Training Years of experience Driver age
Physiological Factors	Driver health (heart attack or other physical impairment) Visual capabilities [visual acuity, useful field of view (UFOV)] Cognitive abilities (decisionmaking, information processing) Strength Fitness to drive
Attitudinal Factors	Attitudes toward safety Moderate or severe crash history Driving habits
Information Gathering	Distraction (internal or external) Poor situation awareness Failure to recognize hazard Inadequate visual surveillance
Driver State	Impaired (alcohol or medications) Aggressive Drowsy Asleep Capacity limited
Organizational Factors	Stop work (vehicle condition) Always swerve to avoid collision Get the work out Productivity incentives Onboard computer (OBC) monitoring Coaching and positive reinforcement Family education to support the driver getting proper rest and nourishment Pre-shift screening of "fitness for duty" Hours of Service regulations Second jobs not always monitored Multiple paper logs

2.3 Summary of Findings from the Root Cause Analysis

2.3.1 PAR Findings

Table 4 shows the results from the PAR reviews and indicates which contributing factors are associated with the specific unsafe driver acts across all crash reports. The unsafe acts that are most frequently identified are driving too fast for conditions, illegal maneuvering or improper turning, inadequate evasive action, and poor directional control. In each of these unsafe acts, information gathering is identified as the chief contributing factor (7 of 11 for unsafe acts); 17 of 19 for illegal maneuvering or improper turning; 8 of 12 for inadequate evasive action; and 36 out of 55 for poor directional control. In all, information gathering accounts for 72% of identified contributing factors, followed by driver state, which accounts for 19% of identified contributing factors.

Information gathering includes such characteristics as distraction, poor situational awareness, failure to recognize a hazard, and inadequate visual surveillance—in short, instances of not paying attention. *Driver state* includes such characteristics as impairment (e.g., alcohol, drugs, or medications), aggressive behavior, drowsiness, being asleep, or having limited capacity—in short, not being fit for duty or in the proper condition or state of mind at the time of the crash. Of course, there are numerous contributing factors, and the accident reports do not provide any further details to uncover further root factors such as training, fitness for duty, effectiveness of training, fatigue, and so forth. The research will show that motor carriers and others need to successfully employ a range of good practices to reduce the likelihood of their drivers finding themselves in a harmful or fatal situation as a result of not paying attention. In fact, even the best drivers will attest to finding themselves in such situations, but were simply lucky enough that they did not have harmful or fatal results. In addition to the summary Table 4, a report annotation table that holds key descriptive information from the narrative data field is provided online in Appendix A.

2.3.2 TIFA Findings

TIFA again shows that driver-related factors are significant contributors to fatal cargo tank truck crashes. The 3 years of

Table 4. Contributing factors associated with the unsafe driver acts identified across crash reports.

Unsafe Driver Acts	Contributing Factors								
	Personal	Physiological	Attitudinal	Driver State	Organizational	Info Gathering	Subtotal Specified	None Specified	Row Total
Too fast for conditions – unsafe speed – uncontrolled speed – turning too fast				4		7	11	112	**123**
Too slow for traffic stream									**0**
Following too closely – sudden slow or stop								5	**5**
False assumption of other road user's actions								2	**2**
Illegal maneuver or improper turning – other improper driving action – turned when unsafe – wrong side – fail to yield	1	1				17	19	37	**56**
Failure to turn on head lamps – turning signal								2	**2**
Inadequate evasive action		2		2		8	12	17	**29**
Panic or freezing									
Overcompensation				1		6	7	22	**29**
Poor directional control (careless driving) – drifting – passing – veering – parking	1	5		13		36	55	93	**148**
Failed to take heed to signage – road signs – yield signs – traffic lights						3	3	7	**10**
Unknown								3	**3**
Total for each contributing factor	**2**	**8**	**0**	**20**	**0**	**77**	**107**	**300**	**407**

TIFA data made it possible to analyze multiple- and single-vehicle fatal truck crashes separately and obtain some significant findings. Driver-related factors are much more likely to be associated with single-vehicle fatal truck crashes than they are in multiple-vehicle crashes involving trucks. The analyses clearly showed that driver factors such as driving too fast or failure to control the rig (e.g., over correcting) were important contributors. Physical or mental condition of the driver was also found to be important. The analyses clearly showed that use of alcohol and the use of drugs (whether taken legally or illegally) are associated with single-vehicle cargo tank truck rollover fatal crashes more often than in multiple-vehicle accidents involving trucks. Similarly, extremely obese drivers—perhaps an indication of being more prone to sleep apnea and, therefore, sleep deprivation—were also more frequently associated with these single-vehicle cargo tank truck rollover fatal crashes. Clearly there are preventable driver factors that are significant contributors such as driving too fast for conditions. The analyses of the TIFA data show that there is room for improved performance through effective driver training and safety programs. Many more details came from the TIFA analysis than are presented here (see the tables and discussion in Appendix B online).

The PAR and TIFA analyses used different contributing factor definitions, due in part to the different information present. The PAR analysis contributing factors were shown in Table 3. The relationships between the two are shown below (see Table 5).

2.3.3 Summary of Key Findings

The separate analyses of TIFA and PARs did yield correlations in potential driver-related root factors. The sources of information do not yield enough to identify absolutely and conclusively the root factors. This would require the type of detailed analysis performed by insurance companies and carriers following major crashes, or the effort that was conducted for the Large Truck Crash Causation Study (LTCCS) (FMCSA, 2006).

Data available from MCMIS, TIFA, HMIRS, and PARs are not sufficiently detailed to conclusively determine driver-related influences. Crash data and accident reports focus more on what happened at the time of the crash and the immediate factors. Combining likely contributing factors, the expertise of the research team, and lessons learned from the interviews, the team has constructed a table of possible influences to the key critical factors.

Using the analysis framework, significant areas of potential driver-related contributing factors include the following:

- Driver state,
- Physiological condition,
- Information gathering,
- Obesity and health,
- Alcohol or drug involvement, and
- Vehicle control.

A number of these areas relate to, or contribute to, the others. Certainly any of the first five areas can result in poor vehicle control, as well as alcohol or drug involvement being considered a characteristic of driver state. Driver state, in turn, can be a factor in—but not the sole causal factor of—information gathering.

Complete information for a thorough root cause analysis is best obtained by thorough investigation. It remains cost-prohibitive to conduct such analysis under the public sector purview for each rollover. Carriers and insurance companies hold the most complete set of information for this analysis, but business reasons prohibit their information being released into the public domain. A process that would allow for root

Table 5. Comparison of PAR and TIFA contributing factors.

PAR Analysis Contributing Factors	TIFA Driver Factors
Personal	Age, race not listed as a driver factor, compiled elsewhere
Physiological	Physical or mental condition
Attitudinal	Operating the vehicle in careless or inattentive manner Aggressive driving or road rage
Driver State	Physical or mental condition
Organizational	Not considered
Info gathering	Possible distractions within vehicle
Vehicle	Blown tire listed under skidding and sliding, brake failure not tied to any driver factor
Environment	Skidding, swerving, and sliding, and also visual obstructions

causes at an aggregate level to be obtained, that would allow for valuable lessons to be shared to improve safety across the industry, and that would provide legal protection and ensure confidentiality to those providing the data is likely the most effective solution to root cause identification of driver-related factors in cargo tank truck rollovers. The analysis did show that it might be worthwhile to study one subset of cargo tank truck rollover crashes: those involving single vehicles. Several of the driver factors associated with these crashes are more prevalent compared with multiple-vehicle crashes. Investigating single-vehicle cargo tank truck rollover crashes would also have the additional advantage that the root and contributing causes of these crashes are more likely to be associated with the driver of the truck and not the driver of another vehicle sharing the roadway. Identifying ways to lessen the role of driver factors in single-vehicle cargo tank truck rollover crashes might translate well to improving highway safety and reducing the incidence of truck crashes involving cargo tank trucks.

CHAPTER 3

Driver Cultural and Lifestyle Practices

This task takes the findings of the root cause analysis to begin to identify other direct or indirect influences on drivers that could cause cargo tank truck rollovers. The initial intent of the research was to be able to identify from the crash data indirect influences such as corporate safety culture and a driver's personal lifestyle. The analysis has confirmed what was identified in *HMCRP Report 1* (Battelle, 2009): crash databases lack sufficient detail to properly identify such indirect influences. The analysis of PARs and TIFA and references from the LTCCS do help us to understand that many rollover crashes are caused by drivers making improper decisions and contributing factors that tie to driver training, fitness, and state of mind at the time of the crash. These contributing factors build up in the hours, days, weeks, and even months or years leading up to the crash.

Interviews helped the research team identify the influences behind the contributing factors identified in Task 1. Tables 6 and 7 correlate contributing factors to potential influences. These are posed as examples or possibilities rather than an exhaustive and strictly defined list of contributing factors. These also reflect input received from the industry experts during interviews in Tasks 3 and 4.

3.1 PAR Analysis Conclusions

Table 6 lists the key contributing driver factors, characteristics, and possible influences from the PAR analysis.

3.2 TIFA Conclusions

Table 7 lists the key contributing driver factors, characteristics, and possible influences from the TIFA analysis.

3.3 Prior TRB Synthesis Research

The effect of safety, management, and communication practices on heavy trucking has been thoroughly studied many times by a number of skilled researchers. Much of what has been learned for commercial vehicle safety in general applies to cargo tank truck rollovers. This literature review highlights the major findings of the more significant studies. An exhaustive literature review was not necessary because that has been ably done by the sources that are cited.

A number of prior studies for the TRB have examined safety, communication, and management practices from one viewpoint or another. Most notable are several in the Commercial Truck and Bus Safety Synthesis Program (CTBSSP). None of them was specific to cargo tank trucks or rollovers, but their findings certainly bear on the task at hand. Table 8 is a brief summary of the more relevant projects.

Two of the CTBSSP studies deserve further discussion. Hickman et al. (2007), in *CTBSSP Synthesis 11: Impact of Behavior-Based Safety Techniques on Commercial Motor Vehicle Drivers*, examined "behavior-based safety" (BBS), whose principles are becoming common in many safety-related industries. In short, the approach is to encourage workers not merely to try to avoid crashes but to refrain from behaviors that are prone to lead to crashes. A key element of BBS is observing behaviors and constructively correcting those that are risky. Peer observation is more difficult for drivers than for those in many other occupations because drivers tend to work alone. Three-fifths of the study's respondents occasionally ride along with a driver to observe. Hickman et al. reviewed a number of onboard safety monitors (OBSMs). These electronic devices record speed, braking force, and other parameters for safety managers to examine. The review discussed their respective capabilities and how they are used by various fleets. A number of the approaches discussed in this study have been implemented, formally or informally, by companies interviewed for Tasks 3 and 4.

Bergoffen et al. (2007), in *CTBSSP Synthesis 12: Commercial Motor Vehicle Carrier Safety Management Certification*, presented a number of management certification programs, some of which are specific to safety and some of which are unique to trucking. Perhaps the most widely known certi-

Table 6. Key contributing driver factors from PAR analysis.

Contributing Driver Factor: Driver State	
Characteristics:	Impairment, mental state (e.g., aggression, depression), drowsiness, sleepiness, fatigue, limited capacity.
Influences may include:	
Fitness for Duty	Driver not fit to perform that day, may not be rested due to family or social schedules.
Health	Driver's physical conditioning, general health, or weight may result in sleeping disorder, low mental acuity, or lack of endurance needed for the job.
Safety Culture	Driver may not see the importance of rest as the individual has not seen an adverse consequence or may be influenced by company or personal (financial or productivity) incentives to compromise in this area.
Hiring	Driver selection process or screening may not identify pre-existing conditions, behaviors, or impairments.
Contributing Driver Factor: Physiological	
Characteristics:	Physical health, vision, cognitive skill and response time, fitness to drive.
Influences may include:	
Fitness for Duty	Driver's physical condition may be deteriorating over time and may not be noticed or addressed by others within the organization. The driver may be an owner-operator or work at a remote terminal and have little, if any, face-to-face interactions with others in industry.
Safety Culture	Driver is not aware of, has not bought into the importance of, or does not participate in a wellness and conditioning program, or the company has not established a health and wellness program beyond the DOT medical and negative drug and alcohol screen as the criteria. Company may not be paying attention to the driver's fitness over time.
Hiring	Driver selection process or screening may not identify pre-existing conditions or impairments.
Contributing Driver Factor: Information Gathering	
Characteristics:	Distraction, poor situational awareness, failure to recognize a hazard, inadequate visual surveillance.
Influences may include:	
Fitness for Duty	Driver not fit to perform that day, may not be rested due to family or social schedules or distracted by family crisis.
Safety Culture	Driver is not aware of, or has not bought into the importance of, maintaining focus and concentration at all times on the road. Company has not stressed the importance to the driver in an ongoing and face-to-face manner.
Operational	Driver is over-reliant on technology to be paying proper attention; cab comforts may have caused him or her to no longer "feel the road."
Dispatch	Driver is on an unfamiliar route or in an unusual situation, which has taxed his or her ability to focus on the situation, the road, and the load.
Training	Driver is not properly trained or is not utilizing defensive driving techniques.

Table 7. Key contributing driver factors from TIFA analysis.

Contributing Driver Factor: Obesity and Health (correlates to Physiological, see Table 6)	
Characteristics:	Extreme obesity, sleep disorder.
Influences may include:	
Fitness for Duty	Driver's physical condition may be deteriorating over time and may not be noticed or addressed by others within the organization. Driver may be an owner-operator and have little, if any, face-to-face interactions with others in industry.
Safety Culture	Driver is not aware of, has not bought into the importance of, or does not participate in a wellness and conditioning program, or the company has not established a health and wellness program beyond the DOT medical and negative drug and alcohol screen as the criteria. Company may not be paying attention to the driver's fitness over time.
Hiring	Driver selection process or screening may not identify pre-existing conditions or impairments.
Contributing Driver Factor: Alcohol and Drug Involvement	
Characteristics:	Alcohol and drug use, including prescription and over the counter (OTC) medications.
Influences may include:	
Fitness for Duty	Driver is not fit to operate the vehicle.
Safety Culture	Company does not regularly reinforce the requirement to report medications, does not provide treatment, or lacks awareness of the driver's addiction or use.
Training	Driver is not aware of requirement to report medications or is not aware of dangers of self-medication.
Hiring	Insufficient background screening.
Contributing Driver Factor: Maneuvering and Control	
Characteristics:	Oversteering, speeding, too fast for conditions, following too closely, overcompensation, poor situational awareness.
Influences may include:	
Fitness for Duty	Driver is not fit to perform that day.
Safety Culture	Driver is not aware of, or has not bought into the importance of, maintaining focus and concentration at all times on the road.
Operational	Driver is over-reliant on technology to be paying proper attention; cab comforts may have caused him or her to no longer "feel the road."
Dispatch	Driver is unfamiliar with the route—for example, the dangerous curve or soft shoulder that has caused other rollovers in the past.
Training	Driver is not properly trained to handle the situation, has let instincts rather than training take over, or is not utilizing defensive driving techniques.

Table 8. Summaries of selected TRB CTBSSP reports.

CTBSSP Synthesis Number, Title, Year, and Authors	Approach	Recommendations	Resources Included
CTBSSP Synthesis 1: Effective Commercial Truck and Bus Safety Management Techniques 2003 Knipling et al.	Twenty-eight management techniques, rated by safety managers and outside experts. Top Five picked by both groups.	Discussion and R&D needs in four opportunity areas: 1. Health, wellness, lifestyle 2. High risk drivers 3. Behavioral safety management 4. Professionalism	Appendix of aids on black ice, rewards, and much else.
CTBSSP Synthesis 4: *Individual Differences and the "High-Risk" Commercial Driver* 2004 Knipling et al.	Surveys and literature review on whether 22 supposed risk factors are associated with crash incidence.	Seven recommendations including identifying whether high-risk traits endure over time and documenting the best driver management practices for use by carrier safety managers and dissemination of this information throughout the industry.	Appendix F has tools for improved driver selection and retention. Survey of risk opinions summarized in Table 3. Hiring practices summarized in Table 4.
CTBSSP Synthesis 11: *Impact of Behavior-Based Safety Techniques on Commercial Motor* *Vehicle Drivers* 2007 Hickman et al.	Surveys and literature search. Asked managers to rate the effectiveness of certain BBS techniques. Table 4 on pg. 28 and subsequent pages.	There are the BBS techniques. Recommendations for research included finding out why managers don't exactly follow research in implementing programs, a naturalistic study on the effectiveness of specific BBS techniques, and whether following procedures or avoiding crashes should be incentivized.	Appendix C has checklists contributed by interviewees. Appendix D has two slide sets on safety.
CTBSSP Synthesis 12: *Commercial Motor Vehicle Carrier Safety Management Certification* 2007 Bergoffen et al.	Literature review and carrier safety manager survey. Management certification may be ISO 9000, Responsible Care, insurance-mandated, government regulations, or other less known programs.	Many of the programs seem to have been designed without an eye toward evaluating their effectiveness. "There is little evidence that programs have been designed with an evaluation process as an integral part or purpose." Recommendation is to establish a committee to evaluate effectiveness.	
CTBSSP Synthesis 13: *Effectiveness of Commercial Motor Vehicle Driver Training* *Curricula and Delivery Methods* 2007 Brock et al.	Literature search, survey, site visit.	Outlines two research plans that could lead to higher standards for commercial vehicle operator training.	Drew conclusions on training content, instructional methods, training the trainer, lack of systematic training design, lack of methods for evaluating effectiveness, and the abilities of individuals coming to training programs.
CTBSSP Synthesis 14: *The Role of Safety Culture in Preventing Commercial Motor Vehicle Crashes* 2007 Short et al.	Literature search. Interviews of carrier safety managers and drivers. Case studies of three carriers.	Stage 1: Assess Safety Culture Stage 2: Identify Safety Culture Improvement Areas Stage 3: Develop Solutions to Improve Safety Culture Stage 4: Implement Safety Culture Improvement Plan and Reassess	List of what works and what does not work is on pg. 23. Future research would be on labor stability, driver influences on culture, and the small carrier conundrum.
CTBSSP Synthesis 15: *Health and Wellness Programs for Commercial Drivers* 2007 Krueger et al.	Literature review, surveys, case studies of four freight carriers and an intercity passenger carrier.	Better tools and off-the-shelf practices are needed for carriers interested in developing their own employee health and wellness programs. The transportation industry needs a paradigm change toward embracing integrated models of health, safety, and productivity as being the joint responsibility of drivers, their managers, and executives.	Link to an OSHA web site on safety and health: www.osha.gov/dcsp/products/topics/businesscase/index.html

fication program within the cargo tank truck business is the Responsible Care® initiative of the members of the American Chemistry Council. Through the International Council of Chemical Associations, Responsible Care is practiced in 53 countries. Responsible Care is a set of broad guidelines within which each company must write a set of policies to adapt the principles to its own situation. Some companies require that those doing business with them be certified to Responsible Care. Bergoffen et al. note that other companies have a less formal list of best practices but nevertheless require those practices as a condition for doing business. Other types of programs allow preferential treatment, such as the privilege of bypassing an inspection station, and some are simply self-imposed standards. Bergoffen et al. observe, "There is a rich and relatively settled set of best practice approaches and processes designed to improve motor carrier safety and reduce crashes and incidents." The report goes on to recommend ways that the management certification programs could be quantitatively evaluated.

Knipling (2009) is a comprehensive examination of the safety of heavy trucks, with several chapters devoted to various driver factors and behaviors and management involvement. The author observes that situational factors, such as driving in dense traffic, influence crash risk (p. 387). Car drivers are more likely to "misbehave" than are truck drivers. Among the human causes of crashes, recognition failures (e.g., inattention) and decision errors (e.g., choosing to go too fast) are significant, while physical factors (such as drowsiness) are also important. The final chapter of the book offers a list of suggestions for preventing large truck crashes (p. 572). Among those that are relevant to the safety, communication, and management practices for preventing cargo tank truck rollovers are the following:

- Good sleep hygiene is more important for alertness and performance than mere compliance with hours of service (HOS) rules.
- Driver selection and evaluation are critical.
- BBS is the most important framework for accident reduction. Onboard safety monitoring should be an integral element of a behavior-based effort, because it captures behavior, which is at the core of risk.
- Risk avoidance strategies—for example, routing off local roads and onto freeways—rival direct crash prevention strategies.
- Driver training, both for novices and the experienced, plays an important supportive role.
- Compliance with regulations should be merely the beginning as a carrier moves toward its own initiatives and internally driven safety aspirations.

CHAPTER 4

Good Practices of the Cargo Tank Truck Industry

This chapter looks primarily within the North American trucking industry for good safety practices. The next chapter will look internationally and outside the trucking industry for practices that can be adapted to the prevention of cargo tank truck rollovers. The bulk of this chapter comes from the interviews that were conducted specifically for cargo tank truck rollovers as part of this project. The objective was to identify the best safety, management, and communication practices that can be used to minimize or eliminate driver errors in the cargo tank truck industry.

4.1 Results of the Interviews

More than 40 telephone interviews were conducted. The largest single group of individuals had a safety oversight position at a tank truck carrier. Federal agencies and trade associations were contacted for their perspectives. Table 9 shows the distribution of respondents' affiliations. Some carriers operate multi-nationally and provided both a domestic and international perspective. Interviews with operations completely outside North America or outside the trucking industry are reported in Chapter 5. A small number of comments from overseas fit better in Task 3; they are identified where they appear. The interview guide is in Appendix C (published online). The questions are categorized according to corporate culture, hiring practices, training, operations, and assessing fitness for duty.

Respondents were given a list of 13 components of a corporate safety culture and were asked to rate them as "very important," "important," "somewhat important," or "not important." Responses were tabulated by assigning "very important" a value of 4, "important" a value of 3, and so forth, and then averaging the scores for each component. The results have little variation with all but one component rated above "important," as shown in Table 10. The lines in the table show there are some break points in the results, but it is difficult to draw any conclusion other than that monetary rewards are considered less important, which is consistent with remarks made in response to other questions.

4.1.1 Opportunities for Improvement

One of the first questions put to carrier safety managers was an open-ended request for which safety management areas could best be improved. A variety of answers was received. The most common response from carriers was the recommendation to monitor the behaviors of drivers. One purpose of monitoring is to identify which individuals need training and in what areas. Two carriers said that hiring practices could be improved. Other answers were more face time with drivers, better fatigue management, drug testing, and post-incident learning. One safety manager noted that the larger carriers share common values; the problem is those who are cutting corners.

The same open-ended question was put to associations and to government agencies. Training and communication were recurring themes. Ongoing supervision of drivers and continuing education were mentioned in some form or another by several respondents. Carriers cannot stop at hiring and initial training policies—they need to continue to actively monitor driver behavior. One observed that waiting until after a crash is not frequent enough to check driver skills.

Ongoing training and continuous improvement are important as changes always occur in the industry, and drivers may develop bad habits over time. This becomes more important as more and more responsibilities are put on the driver, such as loading and unloading. Besides training the drivers for all these duties, the industry as a whole and schedulers in particular need to ensure that the driver can accomplish all that needs to be done without cutting any corners. The representative of one association volunteered that the DOT rollover training video (FMCSA 2010) was effective.

One carriers' association noted the need to attract good, young drivers from other sectors to address the aging work-

Table 9. Distribution of respondents to the surveys.

Primary Job Title	
Federal Agency	4
Industry Association	7
Industry other than Cargo Tank Truck Operator	8
Safety Management	13
Fleet Operations	5
Compliance Manager	1
Corporate Executive	15
Owner-Operator	4
International	5
Sector of the Trucking Industry	
For-hire	14
Private Fleet	10
Primary Type of Business	
Truckload	15
Less-than-Truckload	1
Bulk Tanker	21
Hazmat	22
Specialized	6
Other	1
Power Units Your Fleet Operates	
Less than 50	4
50 – 249	2
250 – 999	5
1,000 – 4,999	4
5,000+	2

force. Though no individual carrier identified this need in answer to the first question, at least two mentioned the age of their driver workforce elsewhere in the interview. One carrier in particular said its driver turnover rate is well below average but the rate will go up as many of its drivers reach retirement age.

Table 10. Respondents' ratings of the importance of components of the safety culture.

Component	Average Rating
Communication from Company Leadership	3.95
Training	3.94
Safety Policies	3.89
Hiring Practices	3.89
Safety Equipment	3.78
Performance Monitoring	3.67
Safety Meetings and Education	3.65
Discipline for Unsafe Behaviors	3.61
Safety Monitoring and Measurement Systems	3.47
Employee Compensation	3.16
Non-Monetary Reward and Recognition	3.11
Safety Incentives	3.06
Monetary Rewards	2.69

Note: 4 = very important, 3 = important, 2 = somewhat important, 1 = not important.

4.1.2 Operations

When asked how a balance is struck between safety and efficiency, two answers were common. One answer was that safety is first, period. The other was that efficiency is not possible without safety because equipment and personnel have to be available to work. If you can be safe, efficiency comes along.

Electronically monitoring drivers' behavior is quite common, although not universal. Some monitors are as simple as maximum speed; others are tied into roll stability systems; many are dedicated systems that record a number of parameters including speeding, hard braking, and cornering. Policies differ on how the results are handled. One only spot checks the data; many post the results with or without identification; some have formulas to rate behavior and identify needs for coaching. Some carriers observe their drivers, either by riding along in the cab or by unannounced observation in a separate vehicle. Those who watch their drivers driving or unloading tell their drivers that the program exists but not when they will be followed. If drivers suspect the company is secretly spying on them, trust will be broken. In response to the question of how the company ensures that drivers understand the training, a few said they test the drivers. The much more common answer was that they observe the drivers, often by having a trainer or senior driver riding along.

Carrier safety managers were asked what fraction of their policies was more proactive as opposed to reactive. Most commonly, carriers reported a majority of 60% to 80% proactive policies. One manager remarked that being proactive is the point of having policies. Most carriers maintain a balance of rewarding good behavior and punishing bad behavior. Reward programs range from simple to elaborate. A few do not have a rewards program—they compensate their employees well and do not feel they need recognition for doing their job.

Time in safety meetings is critical. Aside from the driving skills, tank truck carriers must often cover loading and unloading procedures and hazmat practices, including placarding. At least two carriers have team awards for safety. That conveys the message that everybody at the terminal is working toward a common goal and encourages positive peer pressure. One carrier records all calls between a dispatcher and drivers. That discourages attempting to deliver loads that might not fit a reasonable schedule.

4.1.3 Fitness for Duty

Fitness for duty is covered extensively in Section 6.3. Only a few salient points are mentioned here. The daily assessment of a driver's readiness to carry out the duties of the job varies from nothing at all to elaborate methods. If a driver begins a shift in the middle of the night at a terminal alone, often no one else is present. More than one respondent lamented the lack of personal interaction that accompanies the improvement in operational efficiency afforded by modern electronics. A limited number of carriers use electronics for fitness for duty. One in-cab system has the driver answer a safety-related question when logging in. Another system has the driver perform an electronic eye-hand coordination test several times to establish a personal baseline, and then the test is repeated at the beginning of every shift to compare against the baseline.

Carriers permit drivers to take a day off when they are sick, but sick pay is uncommon.

During a face-to-face meeting of the driver and dispatcher or supervisor, the two can discuss weather, assigned loads, journey plans, and unique risks of the day. During this time the supervisor is observing whether the driver is well and ready. Personal time between the driver and others is more common and more likely to be lengthy in some cultures outside the United States.

4.1.4 Hiring and Initial Training

Minimum driving experience requirements vary, although none of the carriers consider tank truck driving an entry-level position and more specialized carriers typically require prior tanker experience. Nearly all the larger carriers review applications in a central location to ensure uniform application of their high standards. An owner of a small operation said that one of the advantages of being small is that he can hire people he already knows.

Carriers have gotten creative in finding new ways to screen applicants. Taking referrals from current employees is not new, but checking Facebook for risky hobbies is. A hair test is becoming more common than a fluid test for drugs. Carriers are checking the personal driving record, not just the professional record. Most carriers reported using multi-day hiring programs for each new driver, and two required prospective hires to complete a battery of tests demonstrating competence prior to extending a job offer.

Carriers were asked if there are any “deal killers” in an applicant’s background. Many answered DUI, and a few mentioned aggressive or reckless driving, a history of speeding, or felonies. Some, but not all, said they would consider mitigating circumstances if time has elapsed since a DUI conviction. The two most lenient carriers permitted DUI convictions if they were more than 3 or 5 years before. One carrier said that his company will not hire a driver whose value system shows aggressive tendencies or an undisciplined lifestyle.

Carriers commonly have a trainer ride with a new driver before the driver is allowed to drive solo. These periods ranged from 3 to 6 weeks. One carrier had a 1-week minimum. Some carriers require drivers to pass a post-training test before allowing them to operate the company’s trucks.

A driver said that training should be more than simply telling drivers not to have a rollover: it should tell them how to avoid rollovers. Another driver went a step further saying that his training had been focused on not getting into situations that can lead to a rollover. But the driver wished there had been training on what to do if a bad situation suddenly develops. Both drivers and managers observed that the proper action in some circumstances is not to follow intuition or reflexes, so corrective actions must be trained and planned before the need for a split-second decision arises.

A driver who is new to the company, or new to the industry, would benefit from a realistic discussion of the lifestyle that accompanies the profession. Some carriers ask a recently hired driver to have a heart-to-heart talk with a candidate about the realities of the schedule. Some carriers administer a psychological test for fitness to the job. This is also the opportunity to coach new drivers on the need to have proper rest during their off time and not to try to hold a second job or to provide day care. Much of this is second nature to experienced drivers, so compiling a list of talking points is straightforward; the advantages of formally communicating the information to the candidate are great. More than once the suggestion was raised in interviews that drivers be shown photographs or movies of frightening crashes so they appreciate how dangerous the job can be.

There is general agreement among drivers and safety managers on the need for standards in training. Drivers related stories of inadequate preparation, and managers lament the lack of a means of rating driving schools. Further information is in *CTBSSP Synthesis 4: Individual Differences and the “High-Risk” Commercial Driver* (Knipling et al., 2004).

4.2 Noteworthy Emerging Practices

A number of emerging practices were distilled from the interviews. They are already in place at a few early adopters or were suggested by remarks during the interviews. The most prominent emerging practices were selected for the Case Studies in Chapter 6. Others are listed here.

Families play an important role in ensuring the driver returns home safely. For example, the family should not contact a driver 100 miles away to say that the kitchen faucet is leaking. The driver cannot fix the problem from that distance and would be distracted by the additional mental stress. Some companies provide a referral service at the terminal. Family members at home know they can call the terminal for help with small matters. The driver leaves home assured that the family will be cared for even during a multi-day trip. Large companies tend to have such a program in place. The situation is different when the company owner, terminal manager, and driver are all the same individual.

Drivers almost universally (among the interviewees) have stop work authority. Some carriers—in particular, one in hazardous materials transport—give drivers authority not to accept loads that may be misclassified or that create dangerous loading and transport conditions. Drivers beginning a trip on days with possibly inclement weather should be alerted and assured that they will not be penalized for deciding conditions are not suitable for travel. Drivers who exercise their stop work authority are typically required to phone the terminal to report the status, after finding a safe place to stop, if a trip is interrupted.

One of the findings from the international interviews was that truck drivers in some economically depressed regions garner little respect. A carrier found that simply providing a kitchen appliance as a safety award to the driver's family significantly raised the driver's esteem within the family and the community. Clean uniforms set them apart and gave them the pride to want to do their job well. Improving the public perception of truck drivers in North America is a more complex undertaking, but the theme has been mentioned. One carrier allows all drivers to take a guest to dinner when a terminal passes a safety milestone, conveying to the family that the driver is doing a valuable job well. Larger carriers have themed family picnics where, in addition to the conviviality, the need for proper rest during off hours can be reinforced. Posters or lessons on safely driving passenger cars benefit the whole family and remind the drivers of basic safety skills in a non-threatening manner. One consideration would be to reproduce safety demonstrations originated by a high school: students drove a course in a golf cart first without distractions and again while attempting to send a text message.

Key trade associations within several industries have established codes of safe management practice that every association member must adhere to as a condition of membership. This may include a requirement to have the member undergo a third-party audit to certify that the observed practices meet the required codes. *CTBSSP Synthesis 12: Commercial Motor Vehicle Carrier Safety Management Certification* (Bergoffen et al., 2007) examines the benefits of adopting a code of practice.

CHAPTER 5

Good Practices of Other Industries and Countries

Whereas the prior chapter looked at the tank truck industry within the U.S., this one looks at the industry outside the country to achieve cross fertilization. The objective was to identify other industry and international best practices that could be used to minimize or eliminate driver errors in the cargo tank truck industry.

The most noteworthy finding outside the United States was the VicRoads Heavy Vehicle Rollover Prevention Program (see Case Study 1, Chapter 6). Furthermore, a number of companies in other industries had practices in BBS and fitness for duty that can be brought to the cargo tank truck industry; they are treated in Case Studies 2 and 3, respectively. Case studies are presented in Chapter 6.

5.1 Unique Practices and Circumstances of Overseas Operations

Much of what the respondents outside North America had to say corresponded to their domestic counterparts' remarks and do not need to be repeated. A few unique circumstances are mentioned here. One carrier of specialized liquids says its drivers jog around the truck three times before unloading. Besides the informal check of the equipment, the driver's blood gets circulating and the mindset changes from driving to unloading.

The daily fitness-for-duty assessment in some regions outside the United States is more rigorous: it may include a breathalyzer test or a blood pressure measurement. Hourly pay in Thailand is low, requiring workers to have two or three jobs. A carrier there frequently and randomly checks for amphetamines to ensure that drivers are not using drugs to help stay awake. When asked about striking the balance between safety and efficiency, an operator in the Pacific Rim frankly allowed that it is always a struggle to get that balance in developing countries. Improvement is seen with the involvement of multi-national companies, but some countries are decades behind the United States in their high regard for worker safety.

One respondent who had been a driver trainer for many years was recently promoted to the position of terminal manager. He found that he had different performance metrics than previously and that some of them competed with what he had preached to drivers for years. He had to make choices of safety over production metrics. He says that, without changes in perspective, he and the organization would lose credibility. His opinion is that the message has to be the same from all levels; otherwise, workers are left scratching their heads and wondering, "What should I believe today?"

A carrier in a predominantly Muslim country noticed an increase of incidents during Ramadan, when adults fast during daylight. Day drivers rise early to eat a large breakfast and then stay awake after dark for their other large meal. Sleep can be short and, on a full stomach, not the best.

Enforcement of traffic laws varies considerably from country to country. In some places, it is virtually non-existent; in others, it is stricter than in the United States. Singapore requires dangerous goods trucks to have an OBC and global positioning system (GPS) tracking so the truck can be remotely shut down by the government if necessary.

New Zealand has a graduated license program. A driver must go through a progression of lighter vehicles while progressing to driving a heavy, articulated vehicle. During his or her learning period, the driver must be accompanied by a licensed trainer who has held a full New Zealand license for the same class for at least 2 years. A theory test and a medical certificate are required for a learner license. The sequence is

1. A full car (Class 1) driver license for at least 6 months before applying for a Class 2 learner license.
2. A full Class 2 license for at least 6 months (3 months for applicants 25 years or older) before applying for a Class 3 or 4 learner license.

3. A full Class 4 license for 6 months (3 months for applicants 25 years or older) before applying for a Class 5 learner license.

In lieu of experience, applicants over the age of 25 can take an approved course to accelerate the license upgrade to the next class of vehicle.

Drivers who train others for pay must have a separate endorsement on their license. The endorsement requires at least 2 years' experience on the class of vehicle on which training will occur, passing a classroom course, good vision, a medical exam, a check ride, and a "fit and proper person" check. The fit and proper check looks for

- Criminal convictions, including any charges or convictions relating to violent or sexual offenses, drug or firearm offenses, or offenses involving organized criminal activity;
- Transport-related offenses, especially relating to safety;
- History of behavioral problems;
- Past complaints about a transport service the driver has operated; and
- History of persistent failure to pay fines for transport-related offenses.

5.2 Industries Other than Cargo Tank Motor Vehicles

To seek insights in safety from outside the trucking business, team members interviewed representatives from the following industries in which safety is important:

- Pipeline,
- Railroad,
- Mining,
- Aviation,
- Nuclear laboratory,
- Chemical manufacturing, and
- Construction.

Many of the same themes expressed by cargo tank truck carriers emerged—the importance of a safety culture with involvement from all levels of the operation, the need to handle the fatigue that accompanies odd work schedules, and the importance of training. Significant notes taken during the interviews are reported herein.

5.2.1 Culture

A pipeline company recognized a need to shift its safety culture from a "have to" attitude to a "want to" attitude. This required giving employees a larger role in safety and operations, establishing consistency across operational boundaries, placing an emphasis on open communication, and encouraging planning and participation at the field level. By doing so, they are espousing the belief that people matter most.

Similarly, a construction company reported that the industry culture is moving toward a commitment to safety as a team effort. It has therefore become important to spend time getting to know the people who work in the organization. This has come about from recognizing that the industry needs to adjust a culture that had been driven too much by meeting schedule and cost considerations. The contacts here were among those who expressed the theme that emphasis should be placed on motivating employees to follow safe practices, not because they have to do it, but rather because they want to do it. This same theme of "have to" versus "want to" was mentioned by tank truck carriers.

A particular transportation company's safety principles articulated the attitudes that have been heard from other companies on and off the highway. The message is conveyed from top management that safety is paramount:

- All injuries and serious incidents can be prevented,
- Every hazard can be managed,
- Managers are responsible for injury and incident prevention,
- Managers are responsible for knowing how work is actually accomplished in the workplace,
- Everyone's involvement is critical to the success of the corporate safety effort,
- Training is an essential element in an ongoing effort to achieve an injury-free work environment,
- Working safely is a condition of continued employment,
- It is essential to investigate incidents that have the potential to injure or damage health and the environment,
- Safety is good business, and
- Safety off the job is an important component of success in safety.

A transportation company embraces the concept of "behavior-based safety," where the employee is expected to practice safety by focusing on the surroundings. An employee who notices a problem is encouraged to bring it forward without fear of being insubordinate.

A railroad uses peer observation groups to examine at-risk operations. Here, one employee observes how another is performing their work, documenting things that could be improved. These suggestions are meant to be constructive and are non-punitive to the employee whose work habits have been shown to warrant improvement. Out of this process have come better tools and improved procedures that remove risky behaviors. The company considers the time spent by the peer observer to be well worth the effort. (The ability to implement this program required agreement with the appropriate unions.)

The pipeline industry had been on the National Transportation Safety Board's (NTSB's) "Most Wanted List" as needing to address fatigue of control room operators. PHMSA studied the problem and identified that the most frequent human factors contributing to past pipeline accidents were

1. Controller training,
2. Task workload and complexity,
3. Displays and controls, and
4. System information accuracy and access.

The agency subsequently recommended

1. Developing shift rotation practices that minimize fatigue,
2. Limiting controllers to 12-hour shifts unless extraordinary or emergency situations are involved,
3. Scheduling at least a 10-hour break between shifts,
4. Developing guidelines for scheduling controllers that consider the effects of fatigue,
5. Training controllers and supervisors about fatigue, and
6. Ensuring that the control room environment does not induce fatigue.

This subsequently led PHMSA to issue a final rulemaking in 2009 wherein affected pipeline operators must define the roles and responsibilities of controllers and provide them with the necessary information, training, and processes to fulfill them (PHMSA, 2009). Operators must also implement methods to prevent controller fatigue, manage alarms, ensure that control room operations are taken into account when changing pipeline equipment or configurations, and review reportable incidents or accidents to determine whether control room actions contributed to the event.

A transportation company frequently communicates its list of Safety Absolutes, the riskiest behaviors that can get a worker killed. There has been a generational change in the culture of the mining industry from being production-oriented to recognizing that safety and environmental concerns are bottom line issues that must be carefully managed. The more open culture has led to a savvier workplace, so employees feel comfortable pointing out safety problems and recommending potential solutions without fear of reprisal.

An approach first developed by the DuPont Corporation, behavior-based safety is a program whereby the employee is expected to practice safety by focusing on the surroundings. *CTBSSP Synthesis 11: Impact of Behavior-Based Safety Techniques on Commercial Motor Vehicle Drivers* (Hickman et al., 2007) explored how this approach could be brought to the trucking industry. If a problem is noted, the employee is encouraged to bring it forward without fear of retribution. This "coach and counseling" approach is becoming an important element of safe management practice. Elements of this approach include use of peer observation groups, whereby one employee observes how another is performing his or her work and documents activities that could be improved. These suggestions are meant to be constructive and are non-punitive to the employee whose work habits have been shown to warrant improvement. Out of this process have come better tools and improved procedures that remove risky behaviors. Other activities can include voluntary reporting of an employee who appears to be under the influence of a drug or alcohol addiction, which results in the employee receiving counseling, rather than in immediate disciplinary action.

5.2.2 Hiring and Training

A transportation company's rigorous initial training program's high attrition rate effectively weeds out unsuitable candidates who passed the initial employment process. The turnover rate of those who finish the training is low.

A mining company found the leading causes of unsafe operator behaviors to be

1. Inadequate supervision (lack of training and oversight);
2. Technical (equipment design or condition, availability of warnings) and physical working conditions;
3. Lack of worker coordination and communication; and
4. Errors in operator judgment due to routine disruptions or poor decisionmaking.

Within this latter category, the most frequent unsafe acts are attention failure, not following procedures, errors in technique, and poor situational and risk assessment.

5.2.3 Operations

The Federal Railroad Administration has funded a Confidential Close Call Reporting System, a demonstration project to improve safety practices (www.closecallsrail.org/). It is based on learning about potentially unsafe conditions, or close call events, that pose the risk of more serious consequences. The system provides an environment in which railroad employees can voluntarily and confidentially report close calls without fear of discipline or punishment. Information is analyzed to identify trends, new sources of risk, and corrective actions to address them.

A laboratory that does not perform daily routine operations has pre-job briefings so that the supervisor can discuss safety challenges and mitigation strategies, as well as judge the extent to which all involved comprehend what they need to know. On-site safety for the construction company often begins in the design phase, when the management team can examine all aspects of a construction site to identify potential safety risks that could arise during construction and to develop a plan for effectively addressing these concerns. The resulting safety plan can then be reviewed by the construction team. Some companies have each crew member sign off on the plan as evidence that they understand and will follow the accompanying guidelines. Weekly safety meetings are held during construction. A transportation company's comprehensive reward program includes individual and group recognition. Supervisors are given a discretionary budget from which they can issue rewards.

A seamless man-machine interface has significant benefits for safety and productivity. As more warning and communication aids and EOBRs come into truck cabs, careful thought should be given to integrating them in a single man-machine interface rather than adding separate devices individually. Modern control rooms for pipelines and power plants are carefully designed according to human factors principles. Drivers would benefit if such principles were applied in their "control room." This will help drivers not only to avoid distractions, but also to improve response times. If designers heed the psychology of the interface, it will truly aid the drivers, with the components enhancing safety as they were intended.

Kletz (1999) has compiled a set of vignettes from the chemical processing industry. Although the book has no chapter devoted to the overall lessons to be learned from the categorized incidents, it does note that similar or nearly identical events can occur at different plants. One of its recommendations is for safety meetings to review prior incidents so that the knowledge stays fresh as staff changes over the years.

5.3 Lessons from a Prior Study of Disasters

Abkowitz (2008) has analyzed 17 disasters, from natural to man-made to intentional terrorist acts, and has assembled a list of lessons that can be learned from them. Those lessons that are most applicable to the communication and management practices of preventing cargo tank rollovers are discussed below.

- **Risk factors work together to generate an event with disastrous consequences.** The cargo tank truck industry, like most systems and processes, is designed with a built-in margin of safety. When new programs are instituted, they must be treated as a way to increase that margin, not to shift the margin from one place to another. Perhaps the best example of this is that drivers must understand that roll stability control is intended to be a supplement to and not a substitute for professional driving judgment. The adage holds: "Anything an engineer designs into a vehicle, the driver can take back out by going 2 miles per hour faster."
- **Communication failure is a risk factor in every disaster.** Failure can occur when individuals neglect to pass along vital information. This can occur at several levels within a tank truck carrier organization such as between senior management and line supervisors, line supervisors and dispatchers, and dispatchers and drivers. Temporary conditions such as road closures or construction must be promptly conveyed to drivers so that a suitable alternative route can be found or, at a minimum, time can be added to a schedule. Greater awareness of chronically troublesome locations also addresses this lesson. Effective communication is so important to one company that their safety division is bilingual, so as to remove any language barriers in ensuring that every person involved in the operation understands their safety responsibilities.
- **Take planning and preparedness seriously.** Preparedness is often considered a means of dealing with the consequences of a disaster that has occurred, but effective planning and preparedness can also avert or mitigate an impending disaster. In the case of rollovers, this would apply to training drivers to deal with undesirable situations that may develop. One driver said that the training was often an admonition to avoid particular situations, but little training was offered on what to do if one such situation is encountered. For example, keeping all the tires on the road is desirable, but a driver should be prepared in case one tire is suddenly in the gravel shoulder. Another driver commented that passenger car drivers who are unaware of their effect on heavy trucks may put a cargo tank truck in a situation that the professional driver knows is unsafe. The TIFA analysis confirmed what was understood by those familiar with the industry—that many rollovers occur as the result of an evasive maneuver. A dangerous situation can materialize in the blink of an eye. Drivers can learn how to handle dangerous conditions by instruction or, as some carriers do, by simulator experience.
- **Economic pressure is a chronic problem.** One of the interviewees who works with a number of carriers noted that whereas some companies are able to make operations and safety work together for common benefit, for other companies these objectives seem to be continually at odds. As a whole, however, carriers recognized that enhanced safety makes for a more efficient operation. Upper management must therefore clearly communicate to the entire organization that safety is paramount and that they will not brook shortcuts (literal or figurative).
- **Not following procedures is a significant problem.** Imposing a structure and discipline to the performance of repetitive tasks ensures that they are done properly every time. The carriers who were interviewed meet this need by carefully explaining and demonstrating their procedures to new hires, riding with them often for weeks until the new hire is trusted to drive solo. Recurring safety meetings at most carriers and ride-alongs at some carriers ensure that standards are maintained. Written journey plans help

provide consistency between drivers, and drivers are admonished to avoid distractions on the road. Beyond these policies and procedures is an organizational culture that motivates the employee to *want* to do the job properly rather than *have* to do it according to procedure.

- **Arrogance among individuals and organizations is perhaps a far more significant risk factor than previously imagined.** "Cowboy" is a derogatory term for a driver who disregards safety procedures and traffic laws. Part of the better carriers' screening process is to eliminate individuals who may have the basic skills of operating a commercial vehicle but whose attitude is incompatible with handling hazardous materials. Applicants who are considered more likely to take risks or deem themselves invincible are not hired. In those cases in which this screening process is not successful in removing the high-risk driver, the training program presents an additional opportunity to weed out these individuals before they get behind the wheel of a hazmat shipment.
- **It usually takes a disastrous event to convince people that something needs to be done.** Larger carriers have experienced rollovers through the years and appreciate the need for precautions to avoid them. Well-informed smaller carriers have not experienced a disaster, but also realize the importance of a sound safety program. There was no hint that any of the contacts in Task 3 were cavalier, but this lesson from prior research must be taken to heart for the benefit of the entire industry.

CHAPTER 6

Case Studies

The objective of HMCRP Project 13, "The Role of Human Factors in Preventing Cargo Tank Truck Rollovers," is to understand root causes and driver influences that are involved in—and good company practices that seek to mitigate—the approximately 1,200 cargo tank truck rollovers that occur each year in the United States. The risks and stakes are high with cargo tank trucks: liquid contents subject the vehicle to higher centrifugal forces than general cargo, leaving the driver with a smaller margin of error. In fact, the dynamics of many incidents are such that the rollover had already begun before the driver was aware.

Fleet operators—both private and for-hire carriers—invest in technology, operations, and their drivers to reduce rollover incidents. According to ATRI (2011), these drivers tend to be both more experienced and higher paid than the industry average, but the experience alone cannot be counted upon to effectively manage these risks. Safety training, company culture, the constant reinforcement of awareness, vigilance against distractions and fatigue, health and wellness, and the involvement of driver families are the key ingredients in preparing and maintaining drivers for the challenging assignment of driving a cargo tank truck. These case studies address the good practices in place within and outside of the motor carrier industry that can be applied by fleet operators in three major focus areas of the project.

6.1 Case Study 1: Training and Safety Programs

This case study includes a number of tools for terminal managers or carriers in addressing the human side of rollover prevention. While the second and third case studies explore single topics (e.g., behavior-based safety and fitness for duty) more deeply, this case study touches on five topics that can help the carrier to help the driver in avoiding rollovers.

This case study begins with the Australian VicRoads Heavy Vehicle Training Program. The program was developed by VicRoads, a state government roads authority from Victoria, Australia. The discussion of the VicRoads program is followed by four other related topics: the components of an overall safety program, investigating rollovers, using location data, and available training materials.

6.1.1 Overview

The VicRoads program is both a multi-faceted training course and a stepping stone toward developing consistent long-term safety behaviors across the organization. It received highly favorable reviews for its ability to speak to drivers and its results in lowering carriers' rollover rates. By integrating a conventional slide presentation, a video, personal discussions, a model truck on a tilt table for rollover demonstration, and framework to be adapted into a code of behavior, the program communicates through a variety of media and helps the drivers to internalize the message. The largest obstacle to bringing the program to North American cargo tank carriers is not the Australian accents or metric units but the Australian equipment used in the training—logging trucks, agriculture goods, dry freight, and right-hand-drive vehicles. Many in the American test audiences believed that the program is beneficial as it is. Others observed that drivers would not connect as well if the trucks do not look like their own. Even those with reservations about the equipment saw merit in the program. The tank trailer for the VicRoads model truck on a tilt table dramatically demonstrates the effects of a dynamic load.

6.1.2 Case Study Methodology

Information about the program was obtained from VicRoads, and the curriculum materials themselves were reviewed by the project team. The material was shown to audiences of various perspectives within the North American cargo tank industry for their assessment. The checklists in the remaining portions of this case study draw on the earlier sections of this report and the diverse experience of the project team.

6.1.3 VicRoads

The VicRoads Heavy Vehicle Training Program consists of an entire curriculum and includes the media and materials for presenting it. In addition to its comprehensive training materials, it includes a model code of behavior. Drivers, managers, and other stakeholders can revise the code of behavior to make it personal and directly applicable to their own operation. Doing so is a step toward implementing a safety culture in an organization (as in Case Study 2) rather than simply having a one-time seminar.

The training material integrates many methods of presentation, bringing the material to the drivers through a variety of experiences. Like many sets of training materials, it includes a professionally produced video to be interspersed with a set of slides. Its unique and perhaps most powerful feature is a wooden model truck on a tilt table, as shown in Figures 2 through 4. Different types of trailers and loads can be put in the truck to show their effect on the rollover threshold. The model is a way to get the drivers engaged in the training, especially with a skilled presenter.

Most carriers have established driver training programs that include a rollover segment. Portions of the VicRoads materials can be used to complement an existing training program. A complete presentation of the VicRoads package can fill a 1-day rollover training seminar. Implementing the code of behavior is a long-term undertaking.

Elements of the Program

The program consists of four key elements:

1. *Model truck:* Nothing conveys how easy it is to roll a truck better than seeing one go over. A wooden model truck on a tilt board is weighted so that its trailer will go over at the same angle that would take over a real trailer. The instructor can tip the model several times while the drivers watch and understand.
2. *Video:* The video has drivers speaking of personal rollover experiences, other fleet personnel expressing their involvement, and a narrator explaining principles of physics and safety. Footage of several accidental rollovers exemplifies the consequences. Many of the examples are of logging trucks, which also have a high center of gravity, and one of the segments is devoted to tanks.
3. *Presentation:* A series of slides for the instructor to show the students explains the elements of physics at play (e.g., center of gravity, inertia, and centrifugal force); personalizes the message; and stimulates discussion. The presentation includes short video segments and animations.
4. *Framework to develop a code of behavior:* The template is for management and drivers to adapt to their own particular situation. It includes recommended actions for both management (e.g., vehicle selection and trip planning) and drivers (e.g., the speed of vehicles).

Additionally, a guidebook helps managers implement the program. The DVD includes a number of research reports.

Many other practices—such as onboard monitors for speed, daily checks of fitness for duty (FFD), and award picnics for safe drivers—are in place or in progress among carriers in Australia. They are not included in the VicRoads program because it is narrowly targeted on the driving itself.

Some of the components of the wooden model truck on the tilt table are in Figure 2. Different loads can be put on the trailer to demonstrate different effects. The white rod in the clear cylinder simulates a liquid load. When the tilt table is raised slowly, the rod leans toward the lower side of the cylinder (see Figure 3), yielding a lower threshold than if it had remained in place. If the person demonstrating the model gets the rod swinging back and forth to simulate sloshing, the truck can tip over at quite a low angle. The bag of sand and the bag of oatmeal each weigh 2 kg. The bag of sand in the box trailer, as in the figure, simulates a load of gravel. Replacing the sand with the oatmeal is the equivalent of a driver's carrying a load of wood chips instead of gravel. The weight is the same, but the center of gravity is higher, and the roll threshold is noticeably lower. Figure 4 shows how the trailer wheels lift off the pavement before the tractor wheels, as in a real truck.

How the presenters dress is important: mechanics will relate better to someone who is not wearing a suit and tie.

Figure 2. The VicRoads model truck on the tilt table; three loads are shown.

Figure 3. The rod in the cylinder simulates a liquid load in a tank. Note that the rod rolls toward the side even when the table is raised slowly.

Because drivers sometimes have an antagonistic relationship with law enforcement officers, officers do not wear their uniform when they meet with drivers. A road agency shirt identifies who they are, but has been found to be less intimidating. VicRoads reported the same observation as many others interviewed for this project: the whole organization must be oriented toward allowing the driver to drive safely. From the CEO to the truck washer, all have an equal role to play.

Uniqueness of the Program

When asked what sets the VicRoads Heavy Vehicle Rollover Program apart from other rollover programs, the representative said that the numerous other campaigns and videos are only parts, but not the whole, program. It really is four parts—video, presentation, models, and framework to develop a code of behavior—and the power of it is that all of those parts together are more than the sum of the parts.

Figure 4. The trailer tips over at a lower angle with the oatmeal in the trailer than it does with an equal weight of sand.

The objective is to simplify all the parts so that everyone can understand it. No question is regarded as "too dumb" because someone else will always be too scared to ask and someone else will always need to know. The other element is passion. Giving someone a video does nothing more than provide them with something to watch; presenting, answering questions, listening to the problems, and working to fix them really makes the program work better.

A good manager will go a step beyond posters and a video and enable employees to carry out their jobs in a way that is safe, has sufficient time, and is in accordance with traffic laws. It is intended that the carrier use the tools to develop, sustain, or improve a safety culture that incorporates these elements. VicRoads does not create the culture for the carrier, but helps it with tools to change the organization and its approach to rollover prevention.

Outreach

VicRoads currently uses a combination of trade shows and meetings of targeted high-risk groups and industry associations [e.g., the American Trucking Associations (ATA)] to spread the message. They are often asked to do a presentation or information session to help. They also "train the trainer" when asked, typically by safety staff in an organization. The main distribution for these venues is by a DVD pack, which contains the material for the presentation, video clips, the framework code of behavior, model dimensions, research products, supporting information on a DVD, and a guidebook on how to use it. The other method is via VicRoads website, where the material can be downloaded (www.vicroads.vic.gov.au/Home/Moreinfoandservices/HeavyVehicles/VehicleManagementAndSafety/HeavyVehicleRolloverPreventionProgram.htm).

To provide for the owner-operators and small carriers, VicRoads asked larger entities to conduct training sessions so that the smaller operators did not lose out on safety. The bigger companies have agreed to run courses at their own expense and to invite the smaller carriers to the presentations, realizing that training the small carriers may save the life of one of their own. A number of approaches have been taken to encourage the smaller companies to attend the training. Smaller players often get their work by subcontracting from the larger companies. Those with current contracts can be told that attending the training is a condition for renewing the work.

Bringing the VicRoads Program to North America

The VicRoads material was developed by and for Australians. Part of this project was to study what would be involved in bringing the VicRoads program to the tank carriers of North America. To enable this effort, VicRoads sent a number of DVDs with the curriculum and donated the use of a model truck kit. The materials were presented, in abbreviated form, to a group of safety managers and to two medium-size tank carriers. Presentations were made in both the eastern and western United States.

Everyone involved at one carrier—drivers with 3 to 30 years' experience and a manager—wanted to have a full meeting after seeing a brief introduction. Drivers asked questions and learned something they did not previously know or understand. Personnel at another tank carrier said that about a quarter of the VicRoads topics could be highly useful to them. The rest, they thought, do not pertain to them—the logs and hay in the video are not hauled in tanks. They agreed that the discussion of the laws of physics and centrifugal force is germane, but their own in-house material covers those topics. More than one viewer observed that their drivers would relate better if they could picture themselves and their own trucks in the video and slides. Managers from one carrier went further and said that the non-tank trucks would be a mild diversion. It would be difficult showing the VicRoads video to their drivers, telling them to pay attention to some parts but not to the non-tank parts. After hearing the discussion about applicability and similar vehicles, one senior driver spoke up: "A rollover is a rollover, and a driver is a driver." His point was that a driver of any vehicle could benefit by following the material: no special effort is required to bring the curriculum to North America or to tank operations.

The model truck helps to engage the audience. A skillful presenter will make the presentation interactive, asking drivers to predict the angle where the truck will roll over. Some who saw the presentation liked the tube inside the cylinder to simulate a dynamic load (see Figure 3). Some liked the triangles of different heights (see Figure 5). The models are simple and easy to understand.

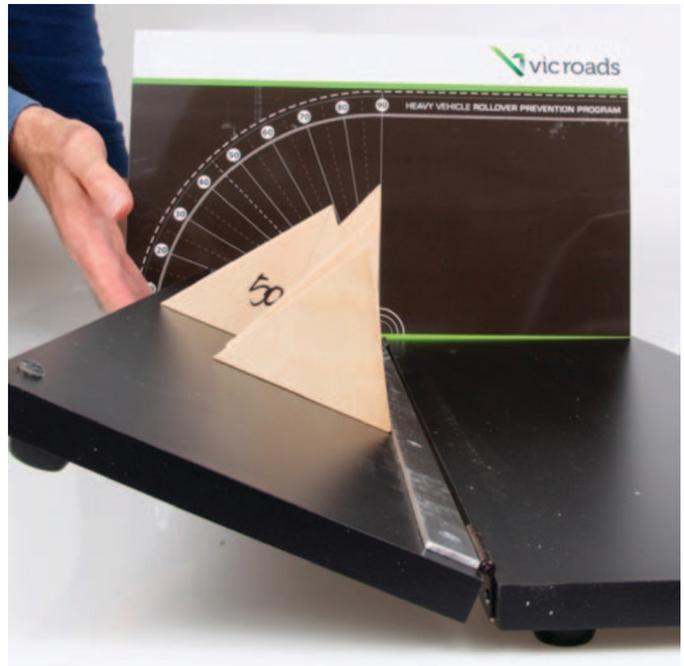

Figure 5. Wooden triangles of various heights and widths convey simply the concept that wider and lower is harder to tip over.

No reviewer expressed an opinion that the Australian accents in the video were an obstacle, and only a few thought that driving on the left side of the road was a mild hindrance. An American editor going through the slides observed that some of the terminology is distinctly Australian. Appropriate American terms were easily substituted after consulting with the material's author. Some did suggest that the narrator ought to be an individual with "instant and strong" credibility. A member of the ATA America's Road Team would be a good candidate.

The final step for making the curriculum available to North American tank carriers is to find a distribution channel. Not every carrier can afford to buy the model truck kit, nor does every terminal need one. A central location can serve as a "lending library" to schedule and ship the kit. The videos, slide presentation, and other electronic materials need to be made available either through a website or from a vendor selling DVDs.

6.1.4 Components of a Good Overall Safety Program

A good overall safety program covers the entire operation. It centers around the driver, but includes everyone else that supports the driver, handles the order, or works with the product. The customer has a role, too. Driver training, such as the VicRoads program, is a key element that must be supported by everything else that happens at the terminal. The spoken message of the training has to be reinforced by everyone's daily actions. The driver's good intentions have to be complemented by the right equipment and by safety-minded schedules and policies.

Certainly, overall safety is a broad topic that cannot be handled here. This discussion includes the factors that are most relevant to rollovers and parallels the themes of the rest of the report—driver, equipment, environment, and culture. (See Appendix D for this discussion in checklist form.)

Adequate, recurrent training is essential. A good safety program engenders a corporate culture in which even small matters are corrected and rules are followed, such as in Case Study 2 in Section 6.2. A corporate safety mindset ensures the driver is fit for duty upon arrival at work, as in Case Study 3 in Section 6.3. A good overall safety program evolves, according to the lessons learned from mishaps—either within the company or in others. If there are no rollovers in recent memory, it's a good thing. The checklist of possible causes under the investigation heading can be a checklist for a model safety program. Make sure those possible precursors are found as soon as they creep in, and not in the investigation of an incident.

The sketch in Figure 6 shows the importance of keeping safety margins in all areas—driver, equipment, culture, and the environment. If all factors are kept in the green zone, then a bad event is unlikely. When only one aspect momentarily lapses into the yellow zone, the protections of the other margins of safety are there to keep trouble at bay. The possibility of a rollover begins to rise when more than one area is in the yellow zone. What may have been a short but adequate following distance on a good day may be too little distance on a rainy day with a tired driver.

Training needs to be refreshed—principles of safe operation need to be in everyone's mind, every day. Training specific to rollovers can begin with one of the curricula discussed in Section 6.1.6; this needs to be reinforced by talks with other drivers and seeing everyone in the entire operation taking all aspects of safety seriously. Over time, drivers may learn the limits of their truck with a certain load and drive to those limits. A number of rollovers have followed a change in load, a change in road conditions, or even a change in tires.

Figure 6. The four main factors of safety—driver, culture, vehicle, and environment—overlap. A good safety program will keep all factors well into the safe zone and away from the margin.

Driver training is more than watching a video or reading a booklet. To truly embed the principles in a driver's daily routine, the drivers need to see people at all levels of the company walking the walk. Training should include discussions among several drivers to talk it over and ask questions.

There are two points that are important to make to a driver who is transitioning from dry freight to a tanker:

1. *The center of gravity of the load in a tanker is almost always higher than it is in other trucks.* Trucks need to take curves at slower speeds than do cars, and tankers need to take them even slower.
2. *The load in a tanker will shift.* The effect in sudden maneuvers is commonly known, but a moving load in a tanker will lower the rollover threshold even in a smooth, steady curve. Many carriers put a partially filled water bottle in the cab for a trainee to watch.

All truck drivers need to keep two caveats constantly in mind:

1. *Rollovers, unlike other kinds of crashes, do not warn the driver they are coming.* An experienced driver can feel when a following distance is too close or see when another driver is erratic. In contrast, because the rollover starts in the semitrailer (or in the pull trailer), the driver in the cab will not sense the impending situation until a rollover is inevitable. Drivers have to be trained to avoid rollovers not by feel—they need to stay well away from the roll threshold.
2. *Excessive speed in a curve is not the primary cause in a majority of rollovers.* Some tankers have rolled because a driver did not properly "square the corner," and the trailer tires came across soft ground and rolled to the *inside* of the curve. Similarly, propane and heating oil deliveries are often on narrow roads where a tire in the soft shoulder can mean a rollover. Many rollovers have occurred when a driver swerves on a straight road segment to avoid stopped traffic ahead. There are a number of potential causes of rollovers, and drivers need to be aware of all of them. Some seasoned veterans even tell of trailers that have rolled after they were dropped. The trailer might be on uneven or soft ground, or the landing gear may have been bent from carelessness.

Several contacts said that discussing mistakes in an honest, non-threatening manner is a valuable learning tool. Drivers can appreciate the conditions leading to a rollover through examples of specific rollovers. They learn what happened and can discuss among themselves what the driver involved in the rollover could have done differently. One national company stands down the entire operation following a rollover until every driver has been briefed on it. (This drastic action also brings home the significance of a rollover.) Larger companies would have their own experience as topics for discussion.

Smaller companies would need to be provided narratives and sketches of rollovers from, perhaps, their insurance carrier. One carrier parked severely damaged vehicles at the terminal before sending them to the salvage yard. It reminds the driver before starting a shift of the malleability of steel.

Some emergency actions required of a driver are counter-intuitive. Perhaps the most obvious is steering straight ahead even if a deer is in the road. Similarly, if a tire suddenly drops off the pavement, the initial reflex to steer it back on must be avoided. The work in these cases would be to compile a list of emergency conditions in which even experienced drivers need refresher coaching. Experienced drivers and safety managers will be asked to give a consensus response to each situation. At a minimum, this could be a topic for a safety meeting. One carrier uses a simulator to run drivers through sudden situations several times until the proper response becomes natural. Student pilots are taught to prevent a plane from stalling, but they also must practice controlling a plane that is stalled. For carriers with the resources, the list of emergency situations can be programmed as a set of simulator scenarios.

Some examples from experience highlight the importance of making safety the responsibility of everyone in the operation. A scheduler needs to appreciate that a truck traveling more than 1,000 miles would not be able to arrive within a 20-minute window. At some plants, the driver of a late truck may have to wait 20 hours to get the next available unloading slot. Similarly, some consignees have a "clock-watching" mentality: they would shut the gates at 4 P.M., regardless of the fact that the truck was just a few miles down the road. These realities can encourage drivers to push the limits to arrive in time.

Many carriers keep a file of "journey plans" for each customer so drivers know to what to expect on a delivery. The journey plan specifies a route and identifies possible hazards such as a sharp turn in the road or a grade leading to the customer's property. It may list an alternative route. Some carriers provide turn-by-turn directions; others do not, listing only the peculiarities and hazards of the route. The journey plan notes whether deliveries are restricted to certain hours. If the customer is a retail service station, the map may indicate the location of vents and overfill indictors. A sample journey plan can be seen in Figure 7. Terminal managers can help drivers to be on guard for systematic causes of rollovers—for example, they can review journey plans with drivers to ensure they are up to date. Managers should ask whether drivers are taking the best route into a service station, or whether they enter from a street that requires the rig be jackknifed as it goes around a curve.

6.1.5 Finding the Root Causes of Rollovers

A mishap of any sort is an interruption to business—with both human and property costs—but it is also an opportunity to improve the operation. By figuring out what led to a rollover, a carrier can make adjustments to prevent it from happening again. The findings of the investigation can be incorporated into the driver training. A proper investigation can take time, but is well worth it—an investigation costs less than a repeat.

Few incidents are the result of a single causal factor but, rather, a combination of factors. Details of the investigative method can vary, but getting to the true root sources of the incident is crucial to keeping another accident sequence from ever beginning. The purpose of this section is to provide direct guidance to investigators in a series of how-to checklists and observations.

After finding a reason, do not be satisfied, but ask why that reason was in place. Realize also that a serious mishap is often the result of many factors all converging at once. It is important to find other contributors that enabled the primary cause to lead to the rollover. In short, the investigation needs to be a process of digging deeper and going broader.

Dig Deeper—Get Beyond the Obvious

Many reports list the root cause of the rollover as, for example, "driver fell asleep." That information is helpful, but it does not provide much guidance in preventing future rollovers of the same nature. A rule telling drivers not to fall asleep could be a solution, but is not effective. It certainly does not fully reveal the cause of the driver's falling asleep:

- Was the driver ill?
- Did the driver stay up to participate in a family activity?
- Did the driver have a second job?
- Was the driver keeping an inaccurate log?
- Does the driver have a medical disorder?
  - Was it diagnosed?
  - Was the driver on medication?
- Did the boss ask for "just one more load"?
- Did the driver recognize the signs of sleepiness, but push on anyway?
  - Why did the driver make that choice?
- Did others in the yard notice signs of fatigue?

Without getting to the real causes, it is nearly impossible to develop and implement solutions.

Another example is not to be satisfied with speed as the root cause. In one crash, the electronic recorder showed that the rollover occurred when a driver new to the company took a certain curve at 44 mph when most drivers took that same curve at 34 mph. Speed was a problem, but it was not the sole cause. After identifying speed, investigators should ask further questions such as

- Was the driver careless on this one trip?
  - If so, what took the driver's mind off the job?
- Did the driver not know the dangers of speed on this curve?
  - Did the journey plan indicate that this turn was a hazard?
  - Why didn't any senior drivers warn the rookie?

Journey Plan Account #: 12345	MY OIL COMPANY
SUPPLY SITE: West Side Terminal DESTINATION: Retail Outlet 12345 9876 Whitefield Road, Anytown, NY SITE CONTACT #: 518 555-1111	SPECIAL DELIVERY INSTRUCTIONS: • High volume location STORAGE (Safe Fill): Regular: 10,000 gals Chart # 201 Premium: 10,000 gals Chart # 201 Diesel: 10,000 gals Chart # 201
RECOMMENDED ROUTE – (Round Trip = 11 miles) • From West Side Terminal, take I-90 east. Exit Herman and take a right. ROUTE HAZARDS: • Possible snow in winter. SITE ENTRY INSTRUCTIONS: • Enter 1ST driveway.	SITE HAZARDS: • High-traffic area and carwash EXIT INSTRUCTIONS/RETURN ROUTE: • Exit onto Herman, turn right onto Whitefield for 2 miles. Take ramp to I-90 W. Exit I-90 at My Terminal Avenue. RETURN ROUTE HAZARDS: • Two on-ramp lanes merge CURRENT TRIP INFORMATION UPDATE: Cocktail bar next door to this station. Do not attempt deliveries between midnight and 3 am.

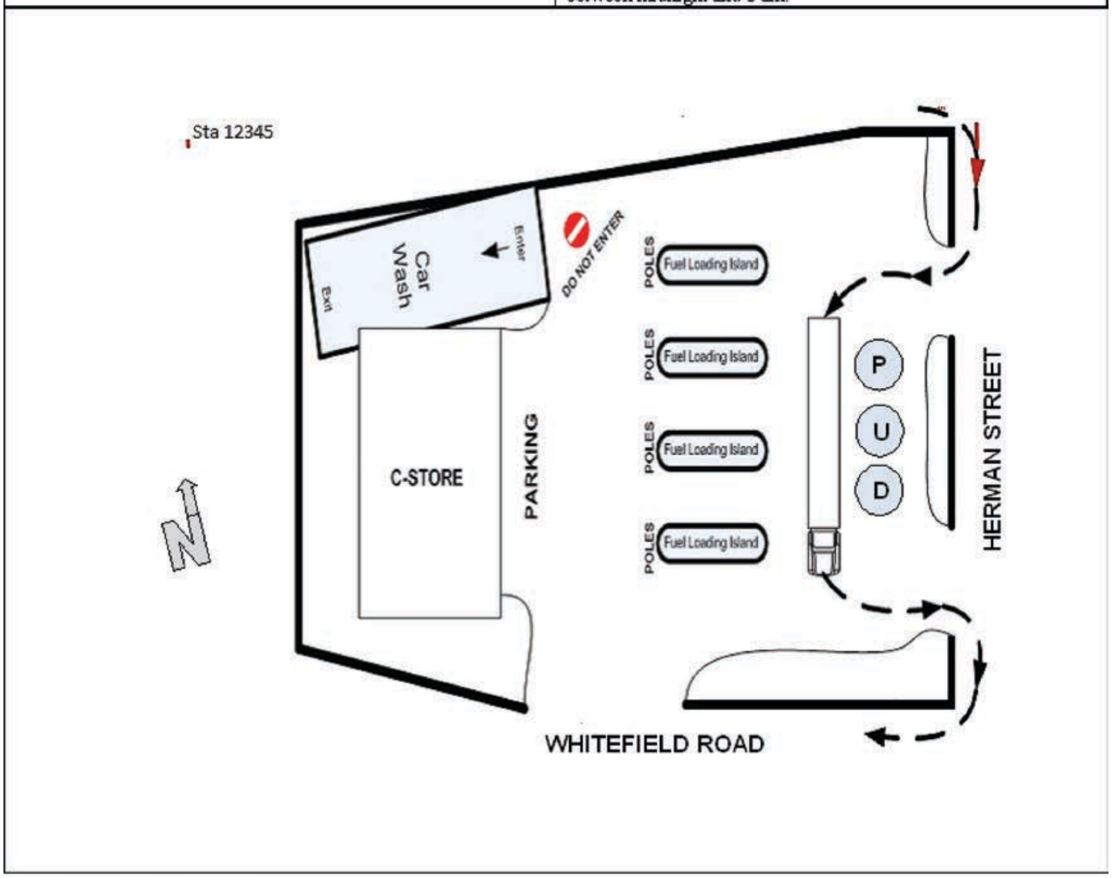

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Figure 7. A sample journey plan.

– Did the driver ignore available information and road signs?
- Was the turn safe at 44 mph when empty, but not when loaded or with a retain?
- Was traffic causing the driver to go faster than was prudent?

Go Broader—Look for Combinations of Factors

Cargo tank rollover accidents, like most incidents, are typically the result of a combination of events. For this reason, it makes sense to view cargo tank rollover accidents as due to factors that collectively erode the safety margin normally associated with routine driving conditions.

In planning an investigation, look at the diverse factors at play in prior rollovers. Chapters 2 and 3 of this report have information on these factors. Appendix A of Pape et al. (2007) has statistics on what factors are often present in cargo tank rollovers. The NTSB investigates accidents from all modes of transportation, including those on the highway. The board's report on the 2009 rollover in Indianapolis (NTSB 2011), though more meticulous than most carriers would conduct, is an example of examining all possible contributing factors.

Many factors are at work, and the investigator needs to understand how they interact with one another. Generally speaking, these factors can be divided into four categories:

1. Driver,
2. Vehicle and equipment,
3. Roadway environment, and
4. Company culture.

Driver. Within this context, there are a number of driver-related factors. These include the following:

- Personal (e.g., experience, training, age);
- Physiological (e.g., health, visual and cognitive capabilities, strength, fitness to drive);
- Attitudinal (e.g., commitment to safety, driving habits, frame of mind);
- Information gathering (e.g., situational awareness, visual surveillance, hazard recognition);
- Driver state (e.g., use of alcohol or medications, alertness, capacity); and
- Organizational (e.g., complying with regulations, properly monitored, gets proper rest).

Analyses of prior cargo tank rollover accidents have shown that any number of these driver-related considerations are present as contributing factors. On accident reports, these factors manifest themselves in actions that are direct causes of the accident: operating too fast for conditions, following too closely, making ill-advised lane or turning maneuvers, poor directional control, and failure to heed signage. If fatigue is suspected, a good resource is NTSB's "Methodology for Investigating Operator Fatigue in a Transportation Accident" (NTSB, 2006).

Equipment. Most tank carriers, especially those hauling hazardous materials, can be expected to keep their vehicles in top shape. Even so, investigators should not automatically discount equipment failure. A pre-trip inspection would be expected to find obvious problems, but does the driver have training on how to find more subtle situations? Was there a procedure for a driver to report a worn part that may not need to be fixed immediately, but should be replaced soon? Was the procedure followed and verified?

Furthermore, vehicle specifications can affect stability. There may be a systemic problem with old equipment that is not as stable as modern equipment (most notably, leaf springs do not resist roll nearly as well as do air suspensions). Equipment factors to consider in the investigation include

- Driver factors:
  - Driver's ability to identify equipment faults during inspections,
  - Tire condition, and
  - Compartment loading for partial loads.
- Mechanical factors:
  - Brake maintenance,
  - Suspension maintenance, and
  - Tire condition.
- Corporate factors:
  - Selection of tires and suspension,
  - Training of drivers and mechanics, and
  - Recordkeeping procedures.

Environment. The roadway environment by itself is rarely the cause of a rollover, but conditions that are less than ideal can allow other factors to become critical. Consider surface conditions, visibility, traffic, and construction.

Culture. Company culture may be the most difficult to examine. Objective criticism will certainly be hard for those in the company. Defects in culture are also more subtle to notice than, for example, a de-beaded tire. Consider the following:

- Do journey plans include all hazards on the route?
- Are journey plans updated with changing traffic patterns, new customers, and so forth?
- Do drivers actually consult journey plans?
- Is training taken seriously?
  - Is it merely a box to be checked annually?
  - Is it crowded out of safety meetings by presentations on revisions to the benefits plan?
- Does everyone in the terminal make safety their own job, from the manager to the accountant to the mechanic?
- Are the principles of behavior-based safety implemented?
  - Were there short cuts or bad habits leading up to this incident that should have been caught earlier?
  - Are there perceived (or worse, real) benefits to cutting corners?
  - Are messages about safety ambiguous?

Tips for Conducting the Investigation

A portion of the most valuable information about a rollover will disappear soon after the rollover, when the vehicle is uprighted and towed. Take photographs, measurements, and interviews promptly. A hazmat carrier would have an established action plan and phone number to call to clean a spill. All carriers should consult with their legal counsel and insurance carrier to develop a similar action plan for gathering and preserving information promptly because certain rules need to be followed.

The purpose of an investigation is to lead to improved company procedures to prevent another rollover. Whether individuals violated company policies and should be disciplined is a separate question. The root cause report will be more generally useful throughout the organization if it includes titles and positions rather than individual names. Also, the process will be less threatening to individuals if they know their name will not appear.

The investigation team should be highly qualified, experienced, and free of apparent conflicts of interest. A driver and a trainer not involved in the incident should be on the team. Smaller organizations may need to bring in a consultant. Team members must keep an open mind and remain objective as the information is gathered. The time to write conclusions will come when all information is in hand. The data should determine the answers—investigators should not seek support for pre-conceived conclusions.

Honest cooperation from every level of the organization and every individual is essential. The process begins with the knowledge that a bad outcome happened. It is almost certain, then, that mistakes and oversights along the way will be found. All must realize that the goal is the greater good of the organization. At the same time, investigators have to be sensitive that egos, reputations, and more are at stake. They need the skill to probe without prying. A way to keep personalities out of the investigation and to ensure the results are credible is to back up comments with records or measurements.

Use the information to make a better operation. A terse investigation report that says "(1) pump broke, (2) pump replaced" has no benefit. If you find that the pump broke because the bearings seized, then examine the maintenance plans and life-cycle expectations. Change the schedule so that the next pump is lubricated more frequently, a different lubricant is used, or the unit is replaced before it reaches the end of the expected life. If you find that the pump broke because the product that was going through it was corroding the moving parts, then specify a different pump and examine the process for selecting equipment. The same principle applies for rollovers. If a truck rolled over because the driver missed the customer's entrance and had to turn around and other drivers agree that the entrance is hard to see, then put better landmarks in the journey plan or change the journey plan to approach the entrance from the other direction. Appendix E (published online) has a simplified investigation report of a fictitious rollover. It shows how a complex sequence of events led to the event and how possible initial conjectures would not be right.

The reason for conducting an investigation is to find the little things that accumulated to lead to the rollover, and then to find a way to stop the little things before they can turn into big things.

6.1.6 List of Available Rollover Training Materials

The U.S. DOT released a video on tank truck rollover prevention in August 2010. Copies were mailed to tank carriers, and it can be downloaded from their website (FMCSA, 2010). The video has been welcomed by many carriers as a fresh, clear presentation of important material. It received a number of compliments. Similarly, the VicRoads Heavy Vehicle Rollover Prevention Program is new. Its freshness and comprehensive approach make it attractive. The video and most of the other VicRoads materials are described on their website: www.vicroads.vic.gov.au/Home/.

Some trainers use information from research studies. One trainer reports that video of crash-test dummies in the cab during a tank rollover dramatically conveys the severity of a rollover. For examples of such videos, see the passenger and driver videos (Videos 11 and 12) from the "Cargo Tank Rollover Force Verification" report (Battelle, 2006). Only a small number of rollover curricula can be purchased as standalone products. One is the "Tanker Safety Awareness Program" (J. J. Keller, 2011). The monthly posters keep the message in front of the minds of all who see them (see Figure 8). Another is the online "Tanker Rollover Training" from LabelMaster.

A number of carriers, including some very small ones, have their own training materials for rollovers and other topics. Some of these carriers have privately shared their written materials or videos with members of the research team. These in-house materials may be specific to a particular operation. Often materials of high quality are not widely distributed. There are some videos that are sent on request, but agreements with the participants prohibit them from being advertised. Other materials are limited to the clients and affiliates of a particular company.

6.1.7 Rollover Crash Location Data

Forewarned is forearmed. Local gasoline distributors with a limited number of customers know their routes intimately. Chemical haulers with a multi-state region, especially newer drivers or those delivering to newer customers, will drive particular roads and ramps less often. In preparing for these trips or writing journey plans for them, knowledge of rollover problem spots would be valuable.

The American Transportation Research Institute (ATRI) has initiated research to collect and analyze data on rollover crash locations throughout the United States in an effort to mitigate truck rollovers. The objective of ATRI's research is to explore innovative methods for identifying sites where heavy truck rollovers are prevalent and to develop an information delivery system to disseminate information about such locations to commercial drivers and other transportation stakeholders.

As a first step, ATRI is merging state-level data on truck rollover events with Fatality Analysis Reporting System (FARS) data to develop a national truck rollover database, effectively mapping the digitized locations where truck rollovers have occurred. Additionally, ATRI is analyzing this database of rollover locations using GIS tools in order to discover truck rollover

Figure 8. Rollover safety posters, Tanker Safety Awareness Program.

clusters or patterns that may indicate areas where instances of large truck rollovers are especially likely. Soon, ATRI will release a publication of "truck rollover hot spots" that will highlight the top ten rollover locations for each state in terms of both the raw number of rollover incidents and rollover rates (expressed as the number of trucks experiencing a rollover per one million trucks operating on a road segment). This publication will be updated as current hot spots are addressed and, consequently, drop off the list, as well as when new hot spots are identified.

Next, ATRI will begin exploring methods for disseminating this high-risk rollover location data to commercial motor vehicle (CMV) operators and transportation stakeholders in two separate phases. In Phase I, the goal is an in-cab warning system to notify CMV operators in real-time when they are nearing a location where truck rollovers are highly likely to occur; doing so will allow drivers to adjust their driving behavior accordingly and lower rollover risk. In Phase II, the focus will be to conduct an analysis of the features of each high-risk location to inform those who have the ability to address infrastructure issues of potential problems related to roadway design or signage. Essentially, Phase I will act as a short-term solution directed at the symptoms (i.e., rollovers), while Phase II will be a longer-term treatment of the underlying causes of those rollovers.

Although many technology providers do not currently make data easily available, an opportunity exists to work with stability system providers and automatically triggered onboard camera providers to glean data relating to stability system interventions or camera events triggered by lateral acceleration above a certain threshold. Information on these near-misses and their locations will also help in developing preventive actions and training.

6.2 Case Study 2: Behavior Management Processes

Many of the carriers interviewed for this research have adopted a behavior-based safety (BBS) management approach to reduce the likelihood of rollovers. The BBS approach has been adopted by many companies in the motor carrier and other industries. BBS focuses on what people do, analyzes why they do it, and then applies a research-supported intervention technique to improve behavioral processes. *CTBSSP Synthesis 11: Impact of Behavior-Based Safety Techniques on Commercial Motor Vehicle Drivers* (Hickman et al., 2007) offers a rich discussion of the history and application of this field.

Figure 9 depicts a simple way of viewing the behavior management process. First, proper techniques and acceptable behavior for a task are identified. Then, the employee is observed performing that task. Observations are analyzed, and behaviors not aligned with or contradictory to approved

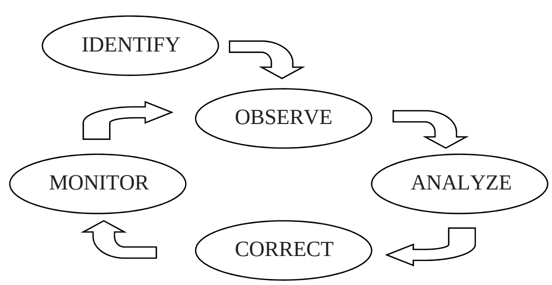

Figure 9. Five-step behavior management process.

methods are noted. The driver must be coached to correct inadequate behaviors. Subsequent behavior is monitored. If behavior does not improve, increasing degrees of intervention are used until ultimately the company makes the decision as to whether such improper behavior will be further tolerated. Good driving behavior has been proven to reduce the chances for a truck crash. Coaching, counseling, and peer-to-peer observation (without reprisal) are fundamental in helping foster good driving behavior.

BBS should blanket the entire organization. BBS helps not only drivers, but also the safety performance of trainers, mechanics, and office personnel. As applied to drivers, BBS includes what happens on the road and ergonomic issues particularly relating to cab ingress and egress, hose and fitting handling, and so forth.

Transportation entities that are well known for having proactive behavior management programs institute a variety of structured and comprehensive strategies. This case study describes recommended behavior management methods, practices, and tools that can lead to improved driver safety and can be employed in a practical manner. While safety is a focus of every aspect of a driver's duties, this case study focuses exclusively on driver behavior while the vehicle is in motion (e.g., intentionally excluding loading and unloading operations). The guide gives examples of good practices used by carriers in the trucking industry and in other transportation modes, coupled with published research findings. It contains valuable information applicable to any cargo tank truck carrier, regardless of company size.

This case study begins with the methodology to identify the kinds of organizations that contributed. A special section describes the practices of carriers outside the cargo tank truck industry. The following sections discuss the five steps in Figure 9. The final section has tips on implementing a behavior management process.

6.2.1 Case Study Methodology

To identify good practices applicable to behavior management in the cargo tank truck industry, the research team conducted in-depth interviews with four for-hire motor carriers, two petroleum product private fleet operators, two U.S. maritime carriers (one inland and one ocean-going), one of the largest U.S. freight railroad companies, and a utility company. The carriers haul hazardous materials as part of their business. They were selected from a subset of those who participated in Phase I (see Chapters 4 and 5) of the project and were interviewed at length on issues related to collecting behavioral data, analyzing behavioral data, identifying problems, selecting and implementing corrective actions, and continuing to monitor driver improvement.

The four motor carriers are safety-award-winning, for-hire companies that run bulk tanker operations. Two haul hazmat, two carry specialized loads, and one is also a truckload carrier. The sizes of these companies varied, with one carrier having fewer than 50 power units, three of intermediate size, and one with more than 1,000 power units. Three of the carriers are considered long-haul, and the fourth is a short-haul regional carrier. Some of the carriers employ owner-operators in addition to company drivers, and one has a majority of owner-operators. Information from these carriers was supplemented with less formal interviews with other carriers and from publication.

6.2.2 Lessons from Transportation Sectors Other Than Cargo Tank Trucks

Much can be learned by observing the practices of carriers in other transportation sectors where behavior management is a fundamental part of an exemplary operational safety program. Such is the case with certain carriers in the maritime and railroad industries.

Maritime Industry

Two marine carriers were interviewed for their behavior management practices. An inland marine carrier uses several sources of information to evaluate wheelhouse operator behavior while the vessel is in motion. These include placement of video cameras in the wheelhouse, use of very high frequency (VHF) radio and radar recordings, and access to data archived by an automated navigation system.

While much of this information could be used to monitor and correct behavior, the culture within the company is not to impose "big brother" surveillance techniques; rather, this information is only accessed and analyzed after the fact and only if there is reason to suspect a problem. Examples include accident investigations and diagnosis of why certain performance indicators, such as travel speed, are outside of an expected range. A manager rides in the wheelhouse with every operator as part of a routine performance assessment, at least annually, and—typically—more frequently.

Wheelhouse operators are also strongly encouraged to minimize personal communication while on duty. However, in the case of extenuating circumstances, use of cell phones, including texting, is permitted. When such communication is necessary, a member of the deck crew is expected to be in the wheelhouse to serve as a lookout. Tools and policies to manage the attentiveness of the wheelhouse operator include

- A policy in which a member of the deck crew enters the wheelhouse every 2 hours to perform an "alertness check" and
- Motion detectors—if the detector does not observe sufficient motion for a 2-minute period, an alarm rings in the bedroom of the duty officer and then throughout the vessel.

These mitigation strategies are indicative of the carrier's commitment to a "zero harm" policy, in which risk is managed through four essential components: (1) leadership, (2) a caring environment, (3) accountability, and (4) developing work plans with risk assessment in mind. Overall, the carrier's investment in behavior management is considered to be time and money well spent.

A deepwater marine operator implemented a personal-based safety program offered by a safety firm. Mid-level management received training and crews received orientation prior to the program go-live date. The company has seen a direct correlation between the implementation of the program and the achievement of a record six consecutive months without a reportable incident. One drawback was that anonymity had been compromised, which diminished crew acceptance of the program. On the other hand, the termination of some who displayed habitually unsafe behaviors subsequently improved both crew acceptance and morale.

Railroad Industry

A rail carrier employs onboard devices to collect data for monitoring operator behavior. The company relies heavily on the locomotive event recorder as a means of detecting situations such as speeding and emergency braking. It is also used to help re-enact conditions that were present as part of post-incident investigation.

In terms of identifying safety problems and causes, the carrier embraces the concept of BBS, discussed earlier in this report. Within this program, all employees are expected to practice safety by focusing on their surroundings. If they detect a problem, they are encouraged to report it without fear of being viewed as insubordinate. In cases where management has identified a previously unreported operator behavior problem, the carrier employs a "coach and counseling" approach that is part of the company culture. The intent is to help the operator understand and correct the identified problem without the use or fear of disciplinary action.

Another behavior management technique is the use of peer observation groups: one employee observes how another is performing work, documenting areas that could be improved. These suggestions are meant to be constructive and are non-punitive to the employee whose work habits have been shown to warrant improvement. This process has produced better tools and improved procedures that remove risky behaviors.

This carrier, and the railroad industry in general, employs an onboard device that provides an audible alert and flashing strobe if there has been a lack of discernible activity by the locomotive engineer over a defined time span. The rationale is that typically an engineer is braking, accelerating, or providing another action during that period of time. If no action is detected, the alarm sounds as a precaution. The engineer can override the alert when it occurs, but if there is no response, an automatic braking application can ensue.

This carrier's investment in behavior management strategies is a reflection of the carrier's belief that safety is the first rule in the railroad industry. As company employees are empowered to work safely, behavior management policies are being employed in a manner consistent with this philosophy. The carrier considers its current practices to be effective in achieving these objectives.

6.2.3 Identification

Identification of behaviors and actions to monitor are common across the industry. Vehicle telematics are used to detect actions such as hard braking, stability control, lane departure events, and so forth. Behaviors can often only be observed, behaviors such as maintaining following distance, keeping eyes scanning, actions at railroad crossings, and so forth. Appendix F and G include the items that are observed during ride-alongs and check rides. First establishing the behaviors and actions to observe and control is important in determining the methods and tools that will be used.

6.2.4 Tools for Observation

There are many approaches to observation, formal and informal, quantitative and qualitative, human and electronic, supervisory and peer-to-peer. When a terminal manager or even a company executive rides with a driver, it tangibly conveys the message to the driver that the supervisor values the driver as an individual and considers safety to be worthwhile. It is an opportunity for two-way communication.

To supplement human observation, a number of electronic means are available for monitoring driving practices. A number of products are on the market to record data and images. Many collision avoidance systems also allow recording of the number of times they are triggered or nearly triggered.

In the better BBS systems, anyone's comment is valuable and any action is fair game. Safety is equally important both inside and outside the cab. However, because this case study focuses on the driving, duties when the truck is parked are not discussed further.

Ride-Alongs

One practice all carriers had in common was the use of management or trainer ride-alongs with drivers. Ride-alongs are useful for gathering data concerning how each driver behaves in the cab. For some carriers, ride-alongs are used as part of new driver certification and tenured driver training and recertification. For all carriers, trainer ride-alongs are more common than management ride-alongs, although one carrier requires all staff, including the president, to conduct a designated number (usually 12) of routine ride-alongs each year. Although these are usually short trips, it sends a strong message of support for the driver's job and it is considered a best practice for developing shared experiences and mutual respect within the company. Ride-alongs can be an evaluation of general behavior (see Appendix F for a check ride form) or an observation of actions (see Appendix G for an observation form). For small carriers who do not use onboard technologies, this may be the key opportunity for identifying problematic behaviors.

One carrier stressed the importance of performing periodic ride-alongs as opposed to only following safety incidents. The rationale is that drivers are more cautious after an incident and tend to be on better than normal behavior. A ride along will tell the supervisor whether the driver knows the right way to do something, but not what the driver will be doing when no one is watching.

Carriers have different approaches to announcing the ride-alongs. Some have a calendar, and a driver might know there will be a passenger next Tuesday. Other supervisors might walk up to a driver at the loading rack and say they are coming along on that load. Some believe that if drivers learn about a ride-along as they start a shift, they are more likely to act naturally, allowing more accurate observation of their habits. One manager noted that a driver may be on best behavior for the first hour of a ride-along, but then will become accustomed to the passenger as the two begin to talk and the driver will revert to normal habits as the shift progresses.

Ride-along observations may be performed by peers, designated senior drivers, safety managers, trainers, direct supervisors, third-party trainers, or other management personnel. Ride-alongs with management can be an opportunity to foster relationships and for management to convey their safety and performance commitment to their drivers and customers. These observations also help management stay informed with operations and learn about issues on specific routes or deliveries that can lead to solutions on a broader scale.

Direct observation by riding along with the driver not only provides a means for collecting data, but also simultaneously provides a means for analyzing causes and monitoring the impact of past corrective actions. Observation includes not only the individual actions, but also the day-to-day behaviors that result in those actions. Simple-but-effective observation techniques are more than adequate for immediate feedback and dialogue to encourage appropriate behaviors and discourage unsafe behaviors. Over time, documented observations by different individuals form an effective database of driver behavior. Supported by a culture of trust and shared values and objectives, observations become accepted as a means of raising the safety and performance of the entire organization. However, the absence of this culture can irreparably damage even the most technically sound program, where drivers may view peer observation's primary unwritten goal as avoidance of management interference.

The effectiveness of peer observations is heavily dependent upon the culture of the organization. Drivers can be skeptical of the safety culture when they become distrustful of management's objectives or of the confidentiality of their reporting. At this point, there is no incentive to provide accurate and actionable input leading to performance improvement of the subject driver. Observers can provide critical feedback when the subject driver trusts and accepts the safety culture. Beyond these environmental issues, personalities or personal conflicts between the participants may limit the effectiveness of the observation.

A small carrier in this study reiterated the importance of ride-alongs to its operation, although it had various methods of collecting driver behavior data. Despite not using any onboard recording equipment (e.g., EOBRs, GPS, or video cameras), the carrier documents delivery information on every trip and thoroughly reviews all paperwork daily.

Some carriers visually monitor drivers from a "chase" car at random, unannounced times. The monitoring program itself is not a secret. All drivers are made aware of the program when they hire on and are expected to perform their duties knowing that at any time they might be under observation. This is somewhat akin to the mystery shopper programs in retail organizations. The companies feel that drivers may perform one way when a passenger is in the cab, but differently when they believe no one is around. Drivers seen exhibiting proper performance are positively recognized, and others receive coaching or discipline commensurate with the transgression.

Electronic Monitors

Electronic monitors can record measurements of the vehicle (like speed and acceleration). Others combine measurements with video images in the cab and possibly in front of the truck. Also, records from crash avoidance systems can be useful in tracking driver behavior. Innovative approaches can combine data with traditional carrier safety management practices to help deter poor decisions of drivers.

Driver Drowsiness Systems

Drowsiness and inattention detection systems use camera technology to monitor the driver's head and eyes and software to analyze the data obtained. Head position and orientation and eyelid blink and eye movement patterns can be analyzed to make allowances (such as brakes or seatbelts) or to alert the driver. Alarms may include sounds; visual displays in the instrument panel; or vibrations in the steering wheel, pedals, or seat (Murphy, 2010).

Electronic Data Recorders and Transmitters

Information and communication technologies, collectively known as "telematics," are used in trucks to communicate with drivers away from the terminal and to record information on driver and vehicle performance. The majority of telematics offerings allow at least some form of communication capabilities ranging from simple phone calls, text messages, and e-mails between the driver and dispatcher to more complex text-to-speech functions. To prevent driver distraction, many of these systems by default blank their screens and hold messages until the vehicle is stationary.

Many telematics systems provide terminals or home offices with near real-time information on truck location, how it is being driven, the amount of fuel being used, and whether there are any (vehicle or driver) compliance issues. Carriers and fleet managers may also be notified when critical events occur (e.g., hard braking, vehicle yaw and pitch motions, driver-initiated alerts) and receive sensor data every second from before, during, and after an incident. Geo-fencing, an enhanced function of some telematics or GPS systems, is used to alert management when a truck strays off an approved route or out of an approved area. This alert helps provide additional security to the cargo and driver and helps ensure that drivers do not deviate from a safe road onto one that might not be as suitable for large vehicles.

Most EOBRs have greater functionality than simply recording drive time: many capture vehicle motion and are capable of fleet management services, including load assignments, location tracking, vehicle diagnostics, navigation, and mobile communications. These optional features are usually available for a monthly service fee. The most commonly requested metrics were reported to be electronic logs, vehicle speed, engine speed (RPMs), cornering, hard braking, stopping distance, near misses, roll stability triggers, lane departures, GPS tracking information, fuel consumption and shifting patterns, regulatory compliance data, and critical events.

Cameras

In-cab cameras received mixed reactions from carrier participants. Carriers agreed that the cameras are excellent coaching tools, providing better insight into what actually occurs inside each driver's cab and revealing any systematic problems. Cameras also provide more information surrounding safety incidents. A few drivers (particularly the more seasoned ones) expressed concern that cameras are an invasion of privacy, and some carriers even cited customer protests against having cameras in their facilities. As is the case with other programs, coaching has to be maintained over the years for effectiveness to be sustained, and feedback has to be equitable and even for all drivers.

An onboard camera and recording system cannot prevent a tanker rollover, but it is invaluable in providing objective information about a driver's behaviors behind the wheel and assisting in incident investigations. Review of triggered recordings and coaching of drivers with questionable behavior can improve habits and reduce the chances of involvement in a rollover or other highway incident. Collision warning systems have the capability of interceding when a driver does something wrong, but it will not tell the terminal what the driver was doing when the technology intervened. Was the driver nodding off? On the phone? A camera system can help provide the answers to why the technology had to alert or intervene. Figure 10 has two examples of images from onboard cameras, along with the speeds recorded by the systems.

Of the two primary types of recording systems—one that is constantly on and archives to an onboard storage medium and one that records short-time segments when triggered—the latter is considered more effective in managing driver behavior. With these systems, audio, video, and vehicle data recordings can be triggered manually by a signal from one of the truck's systems or by sudden vehicle movements (e.g., swerving, hard braking, or lane departures). When triggered, the buffered video is written to a storage device, and recording continues for a set number of seconds beyond the trigger point. A few carriers use cameras to reveal what is occurring

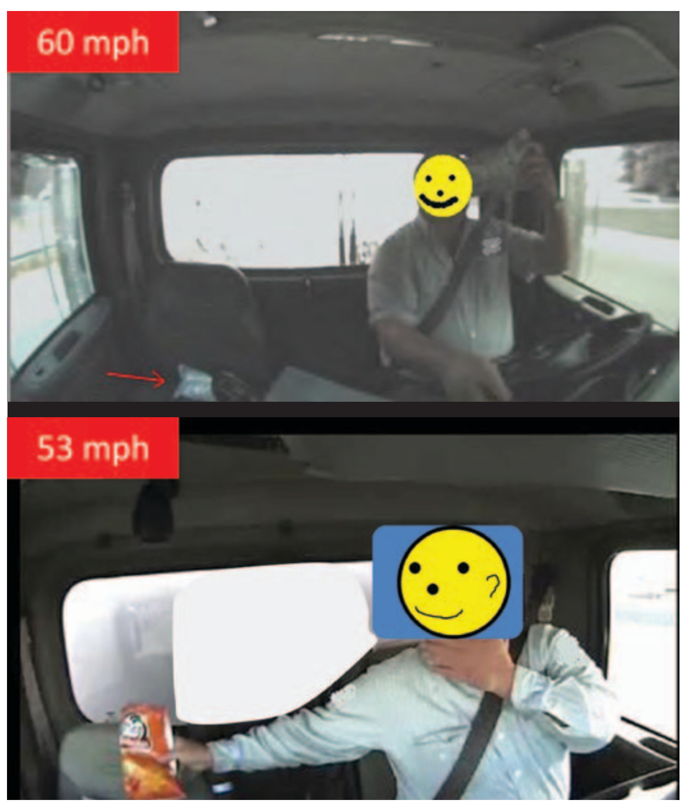

Figure 10. Examples of behavior that, at a minimum, warrant coaching.

inside and in front of the vehicle. Some offerings also use beeps or light-emitting diode (LED) notifications to provide real-time feedback to the driver.

Data collected by the various systems can include speed, g-force, and the date and time of the incident, as well as multiple camera angles and other observations pertinent to the safety event (e.g., running a red light). Data from these technologies are uploaded to network databases, where safety analysts can access them in order to see raw frequencies, establish driver and fleet trends, or identify root causes for specific safety events. This data provides fleet managers and coaches with precise information surrounding safety events as well as being a valuable source of training information.

One for-hire cargo tank carrier was required by its customer to install dual lens in-cab cameras in the customer's dedicated trucks. The customer purchased and installed the equipment for the carrier. With the cameras and stability systems, carrier's crash rate dropped by 46 percent during the first year. Following this experience, the carrier installed equipment in its dedicated trucks for two other major customers (ahead of either customer's contractual requirements for them). The carrier shared the incident reduction figures with its insurance provider. Impressed with the safety improvements and the company's initiative, the insurance provider made a one-time purchase of cameras for the balance of the fleet (non-dedicated vehicles) and lowered their insurance premiums. In the kick-off meeting involving drivers, the carrier conveyed why the cameras were being used, the functionality and how they were going to be used, both to correct bad behavior and to reinforce proper behaviors. The carrier did not face a high level of driver complaints, in part because its initial implementation was contractually mandated. As the systems began to aid drivers in defending against false or exaggerated claims, the acceptance increased.

Crash Avoidance Systems

A number of devices have become available in the past 10 years for alerting the driver to a developing dangerous situation or actually intervening to control stability. Nearly all of them can be used to record incidents and track lapses in driver behavior. These systems offer a variety of options to provide immediate, objective feedback to drivers concerning their behaviors. The goal of these notifications is to alert drivers of impending danger in the short term and help them recognize and change potentially harmful or inefficient driving behaviors in the long term. Many of these systems utilize vehicle sensors that offer collision warning and blind spot warning system functionality, alerting drivers in advance of potentially dangerous vehicle positions. Data may also be transmitted so that driver-specific and fleet-level safety reports can be generated and analyzed.

Considerable research has been funded by FMCSA, the National Highway Traffic Safety Administration (NHTSA), and other entities to estimate the benefits of these technologies and analyze the economics of their implementation (Houser, Murray, Shackleford, Kreeb and Dunn, 2009) (Murray, Shackleford, and Houser, 2009a) (Murray, Shackleford, and Houser, 2009b). A separate study (Murray Keppler, Lueck, M. and Fender 2011) assesses the effectiveness of crash warning systems and other non-traditional approaches to both behavior-based safety and fatigue management.

While these advanced technologies offer beneficial features and services, carriers must take caution to use them in addition to, rather than in place of, regular driver training and coaching. More importantly, drivers must rely on diligence and skill for their safety, rather than develop complacency and reliance on these technologies. Behavior management has been described as more than the sum of its parts, and technology must be integrated into a company's existing safety culture. Nonetheless, the following safety systems and telematics offerings have many attractive features that carriers may find appealing, providing additional opportunities to help manage and monitor a variety of in-cab driving behaviors.

Collision warning systems emit a series of visual and auditory alerts when the truck is operating within a certain distance of the vehicle ahead. They warn the driver when the following distance decreases below a specified threshold. Alerts become more urgent as the following gap diminishes.

Lane departure warning systems (LDWS) are forward-looking, vision-based systems, consisting of a main unit and small video camera mounted on the truck's windshield. The system records data on the truck's state (e.g., lateral position, speed, heading) and the road alignment (e.g., lane width, road curvature) in order to warn drivers when the truck is traveling above a specified speed threshold and is veering into another lane in the absence of a turn signal or other explicit sign that a lane change or departure is intended.

Roll stability control (RSC) systems continuously monitor a moving vehicle's lateral forces, automatically reducing the throttle and applying engine and foundation brakes when the RSC recognizes characteristics indicative of rollover risk (e.g., excessive speed in a curve).

Electronic stability control (ESC) systems have added advanced capabilities to correct for steering in emergency situations—that is, in addition to addressing roll instability, ESC also corrects for yaw instability (i.e., loss of vehicle directional control). Currently, approximately one-quarter of new trucks are sold with some type of roll stability component, usually as an optional feature, however. NHTSA is proposing a rulemaking that will make roll stability systems in (nearly) all new trucks mandatory, while FMCSA may propose that all existing trucks be retrofitted with rollover-prevention technology.

Speed limiters and speed governors are used by trucking companies to control maximum vehicle speed at a specified level. Carriers can set governor speeds with the goal of conserving fuel or preventing speeding.

6.2.5 Methods of Analysis

Carriers without onboard technology rely more on observations and reporting by customers, the public, or compliance agencies. One carrier takes data from these reports and from roadside inspections to create an "evaluation matrix" for each driver's safety record. Based on the results, drivers may be required to take training or retraining focusing on the respective problem areas. This carrier noted that near misses and regulatory compliance issues are leading indicators of risky driver behavior. Some vendors of electronic recording technology offer a complete package of sensors, transmitters, and software to track individual drivers' behavior.

Compliance, Safety, and Accountability (CSA) is FMCSA's new regulatory program, which was launched nationally in December 2010. The program evaluates CMV carrier and driver safety performance by analyzing historical information from a 24-month period. Primarily, the program considers the recency and severity of previous crashes as well as the driver and vehicle violations reported on roadside inspection (RI) reports. These events are filtered into seven Behavior Analysis and Safety Improvement Categories (BASICs) and entered into FMCSA's Carrier and Driver Safety Measurement Systems (CSMS and DSMS) to rate the relative safety performance of carriers and drivers, respectively.

DSMS scores describing driver safety performance are private and can be viewed only by FMCSA personnel during carrier investigations. Employers can access only the raw safety data for each driver that goes into his or her DSMS scores. The rationale for making drivers more visible stems from the fact that a small portion of drivers (10%–15%) account for the majority of safety incidents (30%–50%) (FMCSA, 2004).

CSA provides only limited driver information to their employers and should not be considered a primary behavior management tool. Several companies are offering products designed to assist carriers in managing the FMCSA's new CSA scores. Many systems provide carriers with updated information on the performance of each driver as well as the performance of the fleet, including a breakdown of inspection and violation data and how these affect carrier CSA scores. It should be noted that FMCSA does not provide access to the driver violation histories to these companies, nor does FMCSA validate any vendor's scorecards or data.

Table 11 is an example of one carrier's quantitative analysis of data measured on the road, often referred to as a GYR (green, yellow, red) reporting. There are three measurements: the number of hard braking events, the number of times the vehicle speed was above the maximum limit, and the number of times the engine speed was too high. The reporting criteria were selected from various data available because the carrier felt they were symptomatic of risky driving behaviors—for

Table 11. Example of a quantitative score for drivers.

Driver Name	Raw Data: Number of . . .				Rate per 10,000 miles			Score
	Hard Decels	Over Speeds	Over RPMs	Miles	Hard Decels	Over Speeds	Over RPMs	
					50%	35%	15%	← Weight
Moe	2	2	0	4,403	4.5	4.5	0.0	**96.1**
Larry	2	1	1	3,535	5.7	2.8	2.8	**95.8**
Curly	1	3	0	3,581	2.8	8.4	0.0	**95.7**
Shemp	2	2	0	3,889	5.1	5.1	0.0	**95.6**
Tom	2	2	2	4,397	4.5	4.5	4.5	**95.5**
Dick	2	1	0	2,788	7.2	3.6	0.0	**95.2**
Harry	3	1	0	3,652	8.2	2.7	0.0	**94.9**
Mary	4	1	1	3,864	10.4	2.6	2.6	**93.5**
Spot	3	0	3	2,923	10.3	0.0	10.3	**93.3**
George	3	3	0	3,570	8.4	8.4	0.0	**92.9**
Martha	5	0	0	3,307	15.1	0.0	0.0	**92.4**
Homer	7	0	0	3,883	18.0	0.0	0.0	**91.0**
Bart	7	1	0	4,009	17.5	2.5	0.0	**90.4**
Wilbur	6	2	1	3,677	16.3	5.4	2.7	**89.5**
Orville	4	2	1	2,630	15.2	7.6	3.8	**89.2**
Mickey	7	3	3	4,543	15.4	6.6	6.6	**89.0**
Peter	7	0	0	3,109	22.5	0.0	0.0	**88.7**
Ringo	4	0	0	1,703	23.5	0.0	0.0	**88.3**

example, hard braking can be an indicator of tailgating, inattention, or aggressive driving. All measures are normalized to the number of events in 10,000 miles driving. A weighted average of the metrics is subtracted from 100, and that is the score for each driver. A score above 90 is good. Below 90 requires coaching or further monitoring, and drivers with much lower scores may need further training.

The carrier that implemented this system found it a useful tool, which led to better awareness and smoother driving. After 5 years, most of the fleet was green with a few yellows. Electronics still detected a small number of incidents, and cameras highlighted some opportunities for correction. In an effort to improve further, the safety director examined the criteria and modified them to obtain more improvements. The new criteria raised the bar, and the drivers with lower scores were the ones more often in incidents. Reports like this were posted monthly in the terminal. At first, drivers were identified by number. The drivers figured out who was who, so, ultimately, the carrier switched to using driver names. This added the elements of peer support, pressure, and bragging rights.

Appendix H (published online) has examples of dashboard performance reporting in a graph and a table. Reports can be generated that indicate targeted actions for the driver and when they occur (and even where they occur). Fleet or terminal level reporting can also be developed to evaluate performance against a peer group, such as the fleet or the industry.

6.2.6 Approaches to Correction

The carriers interviewed had driver handbooks that compiled all company policies and procedures, including the consequences of not following them. Along with the written handbook, carriers stressed the importance of making this enforcement visible to all drivers so that they can observe these procedures being actively implemented. Corrective actions depend on the severity and frequency of the action.

Carriers that collect data from onboard technology identify drivers with undesirable behaviors and direct them to intervention with supervisors. More frequent and non-life-threatening behaviors typically can be addressed through standardized remedial training modules that can be modified to specific case circumstances. More dangerous behaviors would require more customized and time-intensive approaches determined on a case-by-case basis.

One carrier also keeps track of positive behaviors and uses a comprehensive bonus pay plan to reward behaviors ranging from safe driving performance to the delivery of favorable service and operating efficiencies. Carriers also keep track of the number of miles each driver and each terminal go without accidents, and two hold banquets or award ceremonies to recognize positive milestones. Some carriers have different categories by terminal size.

Crashes are a vital time to gather data and should be used as a learning opportunity to be fully maximized. Telematics and other vehicle data should be interrogated for information as to the cause and its underlying factors. Case Study 1 of this report provides additional discussion on accident root cause analysis. One carrier circulates "I was there" memos, which associate individuals with stories of safety incidents that can happen when not exercising good behavior, allowing drivers to share their observations and experiences with others. Drivers who have been in safety incidents are also encouraged to share their experience during monthly or quarterly safety meetings so that the group can discuss the issues and learn how to prevent similar incidents. Minor incidents have been displayed on posters; major events have been produced as videos.

All carriers reported using reactive measures to investigate the basis for rollover crashes and other accidents. They investigate the causes by going to the scene and interviewing witnesses. Carriers with telematics utilize data from the onboard equipment immediately before, during, and after the event. Any driver-related contributing factors are addressed by further interviews, warnings, retraining, written records, or other means.

6.2.7 Continued Monitoring

Follow-up action is often required in the case of behavioral issues. As initial expectations are revisited, company leaders will schedule meetings to review driver performance and behavioral data to determine whether remedial actions were effective and sufficient in aligning a driver's behavior with company policies, training, and core values. Carriers use data collection to monitor improvement, including the frequency of target behaviors (e.g., hard braking, roll stability triggers) to determine whether intervention is effective. One carrier uses an evaluation matrix to rate drivers in tracking post-intervention progress.

All carriers agreed that the vast majority of drivers respond positively to interventions and trend toward improved work performance. Safety goals need to be appropriate, yet aggressive, and must incorporate all employees into the process. The process works better if there is wide acceptance and visible participation from everyone in the organization.

6.2.8 Implementing a Behavior Management Process

A strong culture is the most critical success factor identified by the carriers. When asked how a balance is achieved between safety and efficiency, common responses were, "Safety is first, period," and "Efficiency is not possible without safety." The bottom line, as some carriers believe, is that by being safe, you are being efficient.

Small companies do not have the technological and financial resources of larger companies. They must emphasize hiring, retention, training, and ride-alongs. The small carrier in this study reported the significance of employing safety-conscious drivers, which is why their efforts focus on attracting and hiring certain types of drivers who are family oriented. As a result, their staff and drivers know each other well, and most drivers have been with the company for 15 to 20 years.

If carriers rely on onboard technology instead of (rather than in addition to) a value-based safety culture, some drivers will try to "beat the system." A strong safety culture ensures that drivers will do what is in the best interest of the company. Part of safety culture needs to focus on care as for a loved one: carriers encourage their drivers to operate as though the other vehicles they share the road with are occupied by family members. Carriers also try to involve drivers' own family members in the company's safety mission by sending mailings home and inviting family members to award ceremonies and celebration banquets that highlight exceptional performance.

An important part of behavior management includes evaluating the success of a company's behavior management program. All carriers reported that their respective programs were effective in meeting the goals and expectations set at the outset. The practices have more than paid for themselves. Companies report a quantifiable return from their investment in behavior management practices and technologies. Substantial improvements in the rate of accidents, injuries, and workers' compensation cases were seen.

Onboard recorders are often reported as being more cost-effective, less intrusive, and more proactive than in-cab camera systems, while also being more efficient than traditional management or trainer ride-alongs. The features help drivers avoid safety incidents as events unfold in real time, and output from the system allows managers to gain more information in less time (than a ride-along) via individualized driver reports, ratings, and performance trends. Useful as it is, however, electronic recording does not get to the root of what the driver was doing to trigger the alert. Carriers that choose not to install cameras should speak with drivers about specific events that were recorded or perform ride-alongs more frequently.

For some carriers, the process has evolved over time—no longer using a safety firm, the program is overseen in-house. The carrier has also adopted what is believed to be a more behavior-based approach, with feedback and dialogue being emphasized over completion of the checklist. Contributing factors—such as family, attitude, training, and coaching—are included in the discussion.

The Purchase Decision

It is important for carriers to determine what uses and outputs are desired from equipment as they make a purchase decision. This includes identifying target behaviors to monitor or identify. Electronic data recorders can be triggered by events or actions. Subscription-based service providers will evaluate and forward triggered video footage and accompanying data (speed, location, time) based on behavior-tracking criteria determined by the carrier.

Some carriers reached their conclusion qualitatively, whereas other carriers used quantitative approaches to evaluation. Leaders of one company meet regularly to assess the effectiveness of practices. Even when progress is positive, they continually seek additional practices and new technologies that can provide further improvement. As a result, they have seen continuous improvement in multiple safety, operational, and productivity metrics measured annually for the past decade.

One carrier reported that technology vendors and tools were chosen carefully by many departments within the company, based on an analysis of which types of performance they wanted to measure. Another carrier relied heavily on manufacturer input (i.e., the truck manufacturer told the carrier which products would be easiest to incorporate) because the number of available products was overwhelming.

The procurement decision should involve all affected departments in the organization and should be made only after the team has analyzed and agreed on how the systems will be used and the expected outcomes of introducing them into the fleet. Carriers need to first decide which behaviors are of greatest interest and then decide how to measure or observe those behaviors. Original equipment manufacturers (OEMs) can also provide valuable input on which products are most appropriate to incorporate based on the carrier's needs—for instance, carriers with access to onboard technology can request frequency data, scorecards, and driver-specific reports that can establish a myriad of driver and fleet trends in need of improvement. Both long- and short-term costs should be analyzed, including those associated with capital, communications, installation, maintenance, lease, training, and internal support. Some insurance carriers will provide purchasing assistance or offer a reduction in premiums.

Appendix I (published online) provides purchasing decision guidelines used by one fleet manager for in-cab cameras. Many of these same questions can be applied to the purchasing decision for other types of vehicle technology. The key points to consider are life-cycle cost (including maintenance, operations, communications and support) and not just the upfront cost, compatibility with other related systems, and the forms in which data or images can be used for managing driver and operational performance.

Pitfalls to Avoid

Collision avoidance systems can have the unintended consequence of breeding complacency or a false sense of security that the vehicle will self-correct or provide early warning in all dangerous situations. A rollover is a particularly dangerous event in that it can be inevitable before the driver is even aware it has begun. Some carriers reported that driver behavior differed depending on whether the driver believed a truck was equipped with a rollover stability system. Technology is also making cabs and the ride more comfortable. Some drivers report feeling "removed from the road." Ongoing training and safety messages must be employed to help drivers guard against these traps.

Two private fleet operators in the petroleum products distribution business have been industry leaders in safety, extending beyond their private fleets to contract carriers. One operator implemented the program in the 1990s. Results cannot be achieved overnight: the company feels it took 5 years to fully adopt the process. The other operator indicated it took as long as 4 years to see improvements, and 8 to 10 years for an overall level of trust to be developed. Companies that expect immediate results will likely be disappointed, which can result in premature loss of management and financial support or program corrections.

Companies have worked to resolve the evolution of their program into a "paper-chase," where more emphasis was placed on the process and metrics of reporting than on the behaviors that influence safety. When formalizing a driver observation program, it is important to be aware of the effect on driver behaviors and incidents, rather than process metrics.

Rewarding Good Behavior

Carriers create an evaluation matrix from data they have collected and define standards to classify drivers, as was shown in Table 11. A one-size-fits-all approach to behavior management simply does not support strong carrier performance in either operations or safety. Training protocols, ride-along observation schedules, one-on-one meetings with supervisors, and other means for monitoring and providing feedback to drivers should be predicated on their classification. Best class drivers can be in a position to support training and the behavior management process.

Safe behaviors can be rewarded in ways other than compensation. Among all workers, recognition is found to be a strong motivator. Carriers offer recognition to teams (typically terminals) as well as individuals in the form of banquets, company-wide recognition, or names written on the driver's door. One fleet operator with overseas operations provides appliances to the families of their safest drivers, which is a sign of great prestige in their community. These acts are effective not only in rewarding behavior, but are also a highly visible reflection of management's commitment to safety as a top priority and reinforce a shared top-down culture of safety as a core value.

6.3 Case Study 3: Fitness-for-Duty Management Programs

6.3.1 Overview

Cargo tank truck drivers are among the highest paid in the industry (ATRI, 2011) for a reason—the cargo they haul often contains hazardous materials (hazmat) that can be highly destructive if not properly handled. In addition to offering appropriate compensation to attract the most qualified drivers, however, it is also imperative that tank truck carriers pay attention to the mental and physical well-being of their drivers. There are myriad factors related to a driver's well-being that can influence behavior and subsequent safety on the road—for instance, it is known that lifestyle, diet and nutrition, weight, fitness, and physiological, mental, and emotional health can each influence what happens inside the cab and can contribute to problems with driver fatigue and distraction. This case study addresses good practices within and outside of the motor carrier industry for companies that have put programs in place to effectively manage driver fitness for duty (FFD).

Truck driver fatigue is estimated to be an associated (although not necessarily causal) factor in 13% of heavy truck crashes (Blower and Campbell, 2005), while internal or external distractions may play a role in a similar or even higher proportion of crashes including truck rollovers (Olson et al., 2009). The odds of an incident being attributed to fatigue or distraction rise for at-fault incidents, suggesting that rollover risk may be greatly mitigated by addressing chief causal factors (Knipling and Bocanegra, 2008) (Knipling, 2009). As a result of these statistics, many motor carriers have begun adopting best practices aimed at improving FFD. These practices are capable of both reducing costs (associated with accidents, medical bills, and legal fees, etc.) and increasing driver safety, productivity, and quality of life.

Transportation organizations known for designing and implementing good practices relating to FFD programs have instituted structured and comprehensive initiatives. They comprise four major elements: (1) fatigue education and management, (2) general health and wellness, (3) understanding the effects of off-duty behaviors and scheduling issues, and (4) awareness of mental distractions. Coaching, counseling, and family involvement are fundamental tenets of these programs.

The purpose of this case study is to educate cargo tank truck carriers and to provide them with guidance in developing and maintaining effective FFD programs. The highlighted strategies are intended to target cargo tank truck drivers and their families as part of a multi-tiered approach. Managing FFD requires a comprehensive and continuous commitment, touching on all aspects of a driver's daily life. This case study outlines numerous recommended methods, practices, and tools that can achieve that objective and improve driver safety in a practical manner. It contains valuable information applicable to any cargo truck carrier regardless of size and gives examples of best practices utilized by drivers and carriers in the trucking industry and in other transportation modes, coupled with published research findings and other relevant literature.

6.3.2 Key Industry Initiatives in Fitness-for-Duty Management

Fatigue Management

Fatigue can be dangerous for any driver to experience, but especially when transporting hazmat in a top-heavy vehicle susceptible to rollovers triggered by even the slightest human error. Fatigue has been associated with poor decisionmaking, impaired reaction time, and difficulty concentrating, which make the job of a cargo tank truck driver extremely challenging.

Since long work shifts precipitate fatigue, most countries have rules and regulations dictating HOS, which limit the number of hours per day and week that a driver is allowed to operate a CMV. In the United States, 49 CFR Part 395 limits driving time to a maximum of 11 hours, with no more than 14 hours on-duty, followed by 10 consecutive hours off-duty, among other requirements. Even with these requirements, however, some industry stakeholders view HOS standards as too prescriptive and, therefore, inadequate for ensuring that drivers are properly rested and alert. As a result, Fatigue Management Programs (FMPs) have become a burgeoning trend, particularly in North America and Australia, as a flexible and proactive means for dealing with the issue of driver fatigue. Typically, FMPs involve multiple methods and tools that target the entire organization, not just the drivers. In addition to solid HOS compliance monitoring, common features of an FMP include broad educational efforts on issues related to fatigue; scheduling and dispatching; driver health and wellness; sleep disorder screening and treatment; and fatigue management technologies (FMTs).

In Australia, new fatigue management laws were passed by the Australian Transport Council (ATC) in 2007 to recognize the importance of addressing heavy vehicle driver fatigue in a more systematic way (Australian Government, 2007). These laws were backed by years of research demonstrating the positive impact FMPs can have on issues related to fatigue. One 6-year study comparing pre-FMP drivers with FMP drivers found the latter group was less likely to report feeling tired, having difficulty concentrating, or speeding to meet a deadline. They were also more likely to report having an influence over scheduling, having sufficient time for breaks and non-driving work, and having an easier time managing fatigue in general (thanks to management taking an active role) (Smiley, 2010).

In addition to Standard Hours, which are equivalent to HOS regulations in the United States, Australia has established a program for carriers to opt-out of the standard rules in pursuit of either Basic Fatigue Management (BFM) or Advanced Fatigue Management (AFM). BFM adds flexibility to the Standard Hours within determined limits for minimum rest and maximum work hours. AFM takes this a step further and allows operators to propose their own rest and work rules, with further opportunities to extend work hours under specified conditions. In return for the added flexibility of BFMs and AFMs, carriers have greater accountability for managing fatigue risks.

BFMs and AFMs both require National Heavy Vehicle Accreditation Scheme (NHVAS) accreditation, which includes training modules on how to manage fatigue. All parties in the distribution chain are required to take reasonable steps to prevent problems related to fatigue—for example, it is management's responsibility to minimize risk of fatigue by ensuring that scheduling allows for sufficient time to make a delivery as well as to rest and recover during non-shift time.

The BFM and AFM programs carry a number of stringent guidelines, and carrier records must be auditable at all times to ensure compliance. These include scheduling, driver FFD, fatigue management performance evaluation, recordkeeping, health management, and workplace conditions, among others.

The FMCSA and Transport Canada are jointly sponsoring the North American Fatigue Management Program (NAFMP). The purpose of the NAFMP is to develop, implement, and evaluate a comprehensive, integrated FMP for implementation by motor carriers of any size. Key FMP components include commercial driver training and education on sleep need and fatigue countermeasures; training for dispatchers and driver management personnel on improved scheduling, which takes into account individual sleep need; sleep disorder screening and treatment; and fatigue management technologies.

Phases 1–3 of the NAFMP beta tested, pilot tested, and field tested program components with motor carriers in the United States and Canada. Researchers made pre- and post-FMP comparisons of numerous variables related to fatigue and concluded that subjective sleep quality improved and objective sleep duration increased by 20 minutes on on-duty days, with an increased proportion of drivers reporting more than 6 hours of sleep prior to the beginning of their shifts (Smiley, 2010). Reports of fatigue and absenteeism were also lower post-FMP, and critical events dropped by nearly 40%. At the time of this writing, Phase 4—the final phase of the NAFMP—is underway, creating the guidelines and materials that will be needed for motor carriers of any size to implement an FMP within their operations.

Fatigue management technologies have already been evaluated in terms of effectiveness and driver acceptance. One study showed some evidence that technologies could increase driver alertness, fatigue awareness, and sleep time (Dinges et al., 2005). These technologies included driver-interface FMTs, which used body sensors (e.g., wrist watches) or monitored the frequency and duration of eyelid closures to alert drivers of possible impairment and sleep need, and vehicle-interface FMTs, which tracked common indicators of fatigue (e.g., lane drifting) or increased the ease of vehicle control. In general, drivers favored a focus on the vehicle rather than on themselves; however, they noted that FMTs could all be beneficial if further improved.

General Health and Wellness

As a group, commercial truck drivers struggle with a variety of health problems. The typical American truck driver is in his or her mid-forties, which is several years older than the average age of the U.S. workforce (ATA, 2011; Bureau of Labor Statistics, 2010). Obesity rates have also risen faster for truck drivers than for the general population, with close to 50% of truckers having a body mass index (BMI) of higher than 30 (the threshold for distinguishing between overweight and obese) (Truckinginfo, 2011). Truck drivers work long hours with often irregular schedules, are exposed to stressful environments with tight deadlines, and experience traffic congestion and dangerous weather conditions. Job demands also play a role in lifestyle decisions, with little opportunity for exercise or proper diet and nutrition, and a culture that fosters a higher proportion of smokers than found outside the trucking industry (Fuetsch, 2011).

Driver health issues have been implicated in truck-involved fatal crashes, with the NTSB attributing 10% of accidents directly to truck driver health issues in one study (Krueger et al., 2007). The three biggest healthcare expenditures in the trucking industry are hypertension, diabetes, and cardiovascular disease. These conditions are also major risk factors for other crash risk factors such as sleep apnea, which afflicts close to 30% of truck drivers and is more prevalent among obese drivers (Pack et al., 2000; Stoohs et al., 1994). To address these considerations, FMCSA and ATRI have developed a training program called "Gettin' in Gear," which teaches company instructors how to proactively manage driver health and wellness (Krueger and Brewster, 2002). Driver fatigue has also been addressed by ATRI in its development of a train-the-trainer course titled "Mastering Alertness and Managing Driver Fatigue" (Brewster and Krueger, 2005). Additionally, FMCSA and the National Sleep Foundation have partnered to launch a "Get on the Road to Better Health" campaign targeting sleep apnea awareness, diagnosis, and treatment.

Formal health and wellness programs are still uncommon, but individual components are beginning to take hold in many companies. Furthermore, carriers that are serious about improving drivers' health are employing innovative solutions such as creating fitness centers; hiring health professionals and nutritionists; providing tips for better health in newsletters, brochures, and posters; and discounting insurance premiums for drivers who participate in healthier lifestyle choices (Fuetsch, 2011).

Scheduling and Dispatching Strategies

In the trucking industry, fulfilling customer demands while maintaining a balance between one's work and personal life can be difficult. Poor scheduling practices can exacerbate problems associated with both driver fatigue and health and wellness. Susceptibility to fatigue varies by driver, but it is important for schedules to be tailored to the needs of each individual to provide ample time for rest between shifts. Ideally, drivers should obtain at least 7 hours of sleep prior to a shift (Knipling, 2009). Repeatedly failing to do so can contribute to severe sleep debt and a subsequent lack of alertness that may trigger serious safety incidents.

The body's circadian rhythms influence optimal times for resting, eating, and other natural functions, with general low points for alertness during the early morning (midnight–6:00 A.M.) and mid-afternoon (1:00–4:00 P.M.). Disrupting the body's clock by working odd hours can reduce alertness and performance and can decrease the quality and quantity of sleep through abnormal sleeping times. The potential also exists for a build-up of sleep debt if these patterns continue repeating. Evidence that altering sleeping patterns can impact driving performance can be seen by noting the difference in the types of truck crashes that occur during the day and night. Day crashes are often attributed to traffic and passenger vehicle driver behaviors; in contrast, night crashes are more likely to be attributed to driver fatigue (Cades et al., 2011).

Driver Distractions

Distracted driving is the U.S.DOT's number one issue and is a major cause of traffic accidents. However, a majority of research efforts have been exclusively targeted at distractions external to the driver such as interfacing with cell phones and other technologies. This case study's emphasis on distraction focuses on "eyes-on-the-road" mental distractions that steer attention away from the road (e.g., domestic-based stress). When cognitive resources are being used for non-driving purposes, drivers are less able to process information about the roadway and are, therefore, less capable of dealing with safety-critical events (Cades et al., 2011).

While this subset of driver distraction is relatively less well researched than "eyes-off-the-road" distraction, the limitations imposed are the same (i.e., they are equally capable of impairing a driver's alertness and judgment while operating the vehicle). In fact, one transportation study in the aviation industry revealed that domestic-based stress amplifies pilots' perceived work stress and negatively influences their self-rated job performance (Transport Canada, 2011). These findings are relevant to the trucking industry, where mental distractions relating to home life can be supplemented by other stressors like planning for or dealing with traffic, bad weather, or dangerous road conditions. Mental distraction can also be amplified by sleep debt or health conditions, presenting additional safety hazards; therefore, it is critical that trucking companies address the issue of mental distractions in addition to traditional "eyes-off-the-road" distractions in order to reduce the risk for rollovers or other safety incidents.

6.3.3 Good Practices in the Cargo Tank Truck and Other Industries

Methodology

The research team conducted in-depth interviews with five tank truck operators, an inland marine carrier, and a major U.S. freight railroad to identify good practices in FFD management, including the areas of fatigue, health and wellness, scheduling and dispatching, driver lifestyle, and distractions. The five featured motor carriers are all safety award-winning, for-hire companies that run bulk tanker operations. Some also haul hazmat, carry specialized loads, or operate as truckload carriers. The sizes of these companies vary widely, ranging from operating fewer than 50 power units (PUs) to having a fleet with more than 1,000 PUs. Both long- and short-haul carriers are represented, employing both owner-operators (O-Os) and company drivers.

Several cargo tank truck drivers from America's Road Team, a group of drivers honored by ATA for their superior driving skills and safety records, were also interviewed in an anonymous conference call to provide input from the perspective of the driver and the driver's family. They represented medium-size for-hire carriers with bulk tanker, hazmat, and specialized operations. All participants were company drivers as opposed to O-Os or independent contractors, and each had more than 15 years of truck driving experience, with a majority of that time spent in the cargo tank truck industry.

To better inform practices related to FFD management in the tank truck industry, it is important to consider exemplary practices taking place in other industries where safety is important and long shifts are a fact of life. One notable marine transport carrier has instituted several successful programs addressing fatigue education and management and health and wellness. The rationale for investing in these programs is the carrier's commitment to a culture of managing risk so that no injuries to associates, property damage, adverse customer impact, environmental impact, or community harm occur while work is being performed.

Fatigue Management

All tank truck carrier interviewees agreed that the basic building block for creating a sustainable FMP begins with educating personnel at all levels of the company on the causes and corollaries of driver fatigue. Roles and responsibilities for addressing the potential for fatigue must then be customized and made explicit for each position within the company: drivers, executives, safety directors, terminal managers, dispatchers, trainers, and any other personnel who play a role in delivering cargo safely and efficiently. It is important that dispatchers be trained to recognize signs of fatigue when engaging drivers prior to the beginning of a shift. Several carriers described the importance of building a family environment, in which all employees knew each other, as well as their families.

None of the carriers interviewed used psychomotor vigilance tests (PVTs) or any other formal FFD tests to measure alertness since they felt that engaging the driver in a simple conversation prior to the start of a shift provided indicators of fatigue and general demeanor. For one company, if the branch manager or dispatcher is at all uncomfortable about the situation, it is the company's practice to send the driver home. Likewise, drivers are encouraged to notify the employer and switch shifts with another driver if there is any doubt whether the driver can handle a particular shift for any reason. Not all carriers have personnel at all terminals 24/7, so this method has limitations. This underscores why building strong relationships and trust with drivers is an important complement to all practices.

Several participants noted that onboard systems can also be useful in identifying driver fatigue when on the road. Systems that send real-time information—such as difficulty staying in lanes, progressively declining speeds, or hard braking—are excellent indicators that a driver is either fatigued or distracted. Additionally, participants generally agreed that electronic logging (e-logging) devices have helped reduce fatigue since they automatically record the amount of time a driver has been on duty and when their HOS limit has been reached. One carrier displayed a particular commitment to managing fatigue by issuing weekly and monthly fatigue scorecards for all drivers (based, in part, on e-log data and on-duty history), using predictive analytics to proactively identify drivers who are most likely to have an accident.

Driver Feedback. Implementing an effective FMP is considered a shared responsibility in which management and labor work collaboratively to achieve desired outcomes. While carriers may be responsible for providing the means for the driver to obtain sufficient rest, the responsibility is on the individual to utilize their time in the appropriate manner when given the opportunity. Many drivers have admitted that it is difficult to manage their schedule while at home due to the distractions of family and social events. This makes it easy to ignore work responsibilities by decreasing the likelihood of getting adequate rest. Drivers are encouraged to manage their time more efficiently by prioritizing their social schedule with work obligations. More-seasoned drivers reported having a better balance between their work and home life.

There are several tactics drivers should utilize and be familiar with when managing fatigue. It is imperative that they recognize signs of fatigue such as lack of energy, difficulty keeping their eyes open, difficulty concentrating, and drifting in and out of lanes. If any of these signs are evident, the decision should be made—at the discretion of the driver—to pull over and rest, stretch, or walk around. Regardless of what tactic is most effective for the individual, safety should always be the first priority, despite the pressure felt to continue the journey. By recognizing personal limitations and tendencies, each individual can exercise the best judgment in fatigue-related situations.

Other Industries. The railroad industry has also been actively involved in the development of FMPs. This has been motivated in part by recent changes in HOS regulations and other legislation under consideration. Some U.S. rail carriers are patterning their FMPs after an initiative that has been undertaken by Transport Canada (2011). This effort utilizes what is known about the causes and consequences of fatigue in crafting guidelines for designing and implementing an effective rail carrier FMP. While it should be emphasized that this study addresses the rail industry, much of the work product is transferable to the motor carrier industry (see Appendix J, published online). It is therefore used as a basis for the following discussion and recommended guidelines:

- *Extended length of work shift*—Drivers should obtain at least 6 to 8 hours of continuous sleep before beginning extended shifts [consistent with the recommended 7 hours by Knipling (2009)]; however, a driver who has been on a reduced or restricted sleep schedule may need to be more closely monitored.
- *Continuous hours of wakefulness beyond 19 hours*—Research indicates that individuals exhibit a decrease in cognitive performance following 19 hours of wakefulness; therefore, the study recommends companies should enable drivers to nap briefly (20–45 minutes) during a period of 19 hours of continuous wakefulness. Scheduling individuals for duty who have had at least 8 hours of sleep during the prior 24-hour period (preferably during the night before) is another effective countermeasure.
- *Obtaining less than 6 hours of continuous sleep in a 24-hour period*—Research suggests that it is unlikely that a person will obtain more than 6 hours of sleep during daylight hours unless they are extremely exhausted. Individuals who have been working regular daylight hours are unlikely to be able to suddenly switch and obtain the proper amount of sleep during the day. Operators may need to have sufficient recovery time to adjust to schedule changes. The report recommends at least 2 nights of recovery time when switching between day and night shifts.
- *Break times that do not permit reasonable recuperation*—Having adequate time off to recover from the effects of schedules that induce fatigue is essential to obtain the necessary sleep. However, simply allocating this time may not be sufficient to allow recovery if the period is during daylight hours because individuals who have been acclimated to night-time sleep will have difficulty falling asleep during the day. Consequently, the report suggests that there should be sufficient time for the person to obtain the needed rest, which is considered to be at least 8 hours of uninterrupted sleep. Special consideration should be given to individuals who have been acclimated to night-time sleep, as they will be unlikely to obtain this amount of rest during the ensuing daylight hours.
- *Continuous work in a 7-day period*—The report recommends at least 2 nights of sleep before beginning the next work period when having reached the regulatory limit over a 7- or 8-day period. Most experts refer to this as an *anchor sleep* that removes sleep debt and prepares the person for subsequent activities.

The marine carrier has placed the issue of fatigue high on its list of safety priorities and has invested significant resources in teaming with sleep researchers to understand the fatigue phenomenon and how best to manage this problem. Emerging from this process has been the notion of practicing good sleep hygiene, an approach that improves attentiveness while the individual is performing on-duty.

Fatigue is also managed through proactive diagnostics. The carrier believes that an individual's BMI is a strong predictor of a sleep apnea problem. As a result, company policy is that all vessel operators with a BMI of 40 or higher must undergo a sleep apnea test. The correlation between these individuals and diagnosis of a sleep apnea problem has been so high that the company is considering lowering the testing limit to a BMI of 35 or higher.

When a sleep apnea diagnosis is made, the company relies on the sleep researchers to help the individual understand the nature of the problem and how it can be controlled. One particularly effective strategy is to have a member of the research staff who is overweight and using a sleep apnea mitigation device to sit down and talk to the vessel operator who can relate to the problem and is benefiting from the results. Using this approach, the carrier estimates that approximately 50% of its employees are willing recipients of this treatment.

General Health and Wellness

More than one carrier mentioned the need for a health and wellness focus in the tank truck industry given the aging nature of the workforce. The degree of health and wellness interventions varied widely depending on the carrier, but the major components that were identified included

- Fitness and exercise,
- Diet and nutrition,
- Weight loss,
- Smoking cessation, and
- Regular physicals and screenings (e.g., sleep apnea, blood pressure, diabetes, and cardiovascular issues).

Carriers acknowledge that heart disease, diabetes, and hypertension generate the highest costs from a health standpoint, and these areas need to be systematically addressed. In fact, screening for these health issues, as well as sleep apnea, have proven to be valuable in identifying ailments and enabling intervention. As part of these efforts, several carriers stressed the importance of providing affordable medical benefits to company drivers, and most extend these benefits to include all family members.

Most carriers expressed concern for sleep apnea given the proportion of drivers who are overweight, although methods for combating sleep apnea varied. Some carriers focus screening on drivers with BMIs higher than 35 or 40 because these drivers are most likely at risk for the disorder. Testing was considered most affordable by using home kits in which the driver takes the testing device home to wear during the night and then brings it back to work for the employer to ship off for results.

Aside from diagnosing and treating health problems, most of the participants also incorporated diet and nutrition information into their health and wellness programs, as well as creating opportunities that encourage drivers to begin exercising and quit smoking. As a rudimentary first step, most carriers offered drivers basic instruction in these areas using bulletins, pamphlets, or even CDs or cassettes they could listen to on the road.

In an effort to encourage drivers to begin exercising, one carrier offered lifestyle coaches and physical therapists through various resources (in person, by phone, and by email). One carrier provided a worksite fitness center and another offered a discount to a local gym. As an added incentive to eat right and exercise, several carriers created a weight loss competition that offered bonuses and discounted insurance rates to their drivers. Finally, one carrier promoted good health by offering healthy snacks and fruit at their company meetings.

Driver Feedback. Drivers should take advantage of programs and benefits their employers offer and be familiar with any health issues they have in order to get proper treatment. According to both the drivers and carriers interviewed in this study, drivers who participated in health and wellness programs had more energy and were more alert. One driver acknowledged that the program was "like a night and day transformation," noting that results are not immediate, but that the process results in a life change through patience and consistency.

Other Industries. Acknowledging that prevention is such a critical part of health care, the marine carrier recently instituted a policy that all preventive health exams would be fully covered at no cost to the employee. Moreover, because the employer is paying the full cost, the employer has enhanced awareness of preventive health maintenance activities. In an attempt to improve health and wellness, the company offered an additional $300 in health benefits if the employee completed a health risk assessment and used the services of an online wellness coach. The response rate was rather poor (10% participation), but when the program was revamped and offered health benefits only to those who participated in the program, participation jumped to 100%. Therefore, making participation a requirement was much more effective than offering an incentive.

To encourage physical fitness, the carrier has installed a treadmill, elliptical machine, or exercise bike on each vessel. Each shore-based facility also has an area equipped for fitness workouts. In the area of nutrition, the company has begun to offer healthier dining options on vessels, including working with a local university on food preparation in a galley environment.

Scheduling and Lifestyle

According to one of the carriers interviewed, "Drivers are the heart of the trucking industry, and the new generation of drivers is very different from the old one, so carriers need to adjust accordingly instead of clinging to outdated practices."

Driver scheduling practices are strongly correlated to successful FMPs and health and wellness programs. In addition to complying with HOS rules, some proactive measures used by carriers interviewed for this case study include using regular schedules with consistent start times, minimizing driving at night or during heavy traffic, and planning around unfamiliar or dangerous routes. It is important to recognize, however, that scheduling is often customer-driven, so as much as carriers would like to move driving times away from late night or high traffic periods, it is not always possible.

Even when scheduling is out of the employer's control, carriers have an obligation to inform drivers and other personnel of risks associated with driving during certain times of the day. Some carriers teach drivers methods they can utilize to increase alertness during circadian lulls such as taking additional breaks to nap or to walk around. Carriers who had greater flexibility with their schedules report keeping the routes as short and direct as possible. One of the simplest best practices identified in this area was to provide drivers with at least a 24-hour notice before each shift, to ensure sufficient opportunities for drivers to plan for 7 to 8 hours of sleep. Additionally, all of the participants stressed the importance of communicating with drivers to establish the schedule that works best for each driver. Several carriers specifically acknowledged that drivers do not get an adequate amount of rest during holiday hours and have made attempts to provide flexible scheduling or shorter hauls for drivers on these days.

It is important that drivers, dispatchers, shippers, and receivers be educated in order to avoid the risk of safety incidents. Drivers need to understand the importance of time management to ensure adequate amounts of rest during work periods and while off duty. The carrier needs to recognize the unnecessary pressures that can come from shippers and receivers and to help these parties understand practical limitations and the importance of a well-rested driver. Doing so can lead to more reasonable and realistic schedules that build in greater safety margins to accommodate for unexpected delays and drivers' needs for breaks.

Although seeking outside assistance is recommended if this option is offered by the employer, nothing can replace the natural understanding of one's own personal limitations. The ability to balance the relationship between working hours and time spent outside of work will influence the effectiveness of the driver's ability to be better rested and operate safely while on the road. As part of this challenge, drivers are encouraged to resist allowing their social life to interfere with needed rest. They are further encouraged to feel comfortable communicating any scheduling concerns with their supervisors. If a specific scheduling issue is preventing them from attaining a level of safety or quality, it is in both their and the employer's interest to amend the schedule.

Finally, when working during the most dangerous shift for fatigue (i.e., between midnight and 6:00 A.M.), drivers need to be aware of how to combat the body's natural circadian rhythm and sleep patterns. One of the highest risk scenarios is for a person to be awake during the daylight hours and then be expected to work during the ensuing period of midnight to 6:00 A.M. (Transport Canada, 2011). For persons working this shift, it is important to acknowledge the need for time to nap during the midnight hours to the extent that it is operationally feasible and compliant with regulations governing hazardous material shipments, as well as broader operations. It should be noted that naps are no substitute for sufficient sleep [7 hours according to Knipling (2009)] prior to the shift.

Driver Distractions

Carriers must be aware that distractions within the cab include both physical and mental disturbances. The former includes eating and drinking, cell phones, citizen's band (CB) radios, GPS, onboard technologies, and other handheld technology; the latter includes mental distractions (e.g., stress, daydreaming, or preoccupation). One carrier stated that there is a correlation between a driver's family environment and on-duty safety performance—for example, the carrier noted that the 2008 recession resulted in a higher rate of safety issues, which could likely be attributed to drivers worrying about family members' job losses, foreclosures, and financial issues. This carrier offers a way to decrease driver disturbance while on duty by encouraging the spouses to contact the company's terminal for home repair issues and then handles the costs through payroll deductions.

Cell phone use remains a top contributor to vehicle accidents. Several companies have used outreach methods to ask family members to avoid calling the driver's cell phone while he or she is on duty. It was discovered that dispatchers can create the greatest distraction for drivers as a result of calling driver cell phones while they are traveling. Carriers have begun to require that dispatchers rely solely on the company's telematics messaging system to send messages, which are not delivered until the vehicle is stationary.

While most of the carriers participating in this study do not directly monitor distraction while the driver is on the road, they do rely on several other indicators such as information provided from dispatchers or onboard safety systems (OSS). Several case study participants stated that hard braking, difficulty staying in lanes, and progressively declining speeds were effective indicators of distracted or fatigued driving. One carrier also reported acting on "How's my driving?" calls from other motorists and input from customers as effective monitoring tools of behaviors that may indicate fatigue.

Driver Feedback. Drivers reported the natural inclination to be less attentive when taking familiar routes. It is important to be diligent and remember that every vehicle handles differently due to different suspensions or weights, so drivers need to stay focused on the vehicle and the type of cargo they are carrying even when familiar with a route. It was noted by a former driver and fleet manager that familiarity with an assigned vehicle, while it may have benefits to the driver, can also lull that driver into inattentiveness. Another common distraction is cell phone usage while driving. Every driver should be committed to their work while on duty and should avoid taking calls or checking messages, whether personal or work-related, until the vehicle is parked.

Good Practices Involving Driver Families

All of the participating motor carriers and drivers stressed how important family involvement and support are to the success of FMPs and health and wellness programs. To ensure that drivers receive proper rest outside of work, it is necessary for family members to be sensitive to the obligations that the job entails. This may require spouses to be aware of the driver's schedule and to organize events in a way that does not conflict with the driver's sleep regimen. Some of these extra responsibilities might include the spouse participating more in completing household tasks and other domestic obligations.

There are times when a personal phone call is inevitable while the driver is on the road, but it is recommended that such calls be limited to emergency situations and that different tactics be defined in such cases. For example, one driver said his wife knows to call and hang up if there is an emergency and then he knows to pull over at the next opportunity and call her back from a safe place.

Family members can also play a critical role in a driver's health and wellness. Carriers noted that it is the "little things" that contribute to big improvements. Spousal recognition of health-related symptoms is often a critical first step in identifying an unhealthy condition, and the spouse should encourage the driver to seek treatment. Carriers agreed that drivers are more attentive to their spouse than to anyone else, and receiving preventive care is more likely if there is pressure from home.

Several carriers and drivers also cited the spouse as one of the major driving forces for successful weight-loss initiatives, with a driver noting that "the wife is where the pressure comes from—if she isn't happy, no one is happy." Drivers did admit struggling to decline prepared meals, making it difficult at times to commit to healthy food choices. They noted that it helps if the spouse is health conscious and prepares nutritious meals while discouraging unhealthy foods and products like ice cream and tobacco. Finally, families can take small steps to be active together (e.g., taking the dog for a walk, spending time at the gym, or doing stretches together).

Most of the carriers interviewed made some attempt to engage the family in FFD practices. Often, this included mailing newsletters and informational packets to the home and inviting family members to safety meetings. Two companies took this further by holding regular award ceremonies or banquets that families were invited to attend. They also noted that it is important for families to read the information that gets sent home and to participate in company events to further a driver and carrier's sense of commitment toward one another and to share in the FFD process.

6.3.4 Key Components of the Fitness-for-Duty Program

This research makes a compelling argument that it is in the best interest of carriers, drivers, and drivers' families to promote FFD practices in the cargo tank truck industry. It is a shared responsibility, with roles defined for each group that help achieve the overall objective of reducing fatigue, improving health and wellness, and lowering the incidence of safety critical events.

The best practices described are achievable for carriers of all sizes, although those who have more resources may have the added benefit of utilizing external contractors that specialize in these areas. For the larger carriers interviewed, it was common to seek outside help during the development of FMPs, health and wellness programs, and scheduling practices. Roles typically shift back to the carrier at some point, although external providers are most likely to remain involved in health and wellness practices due to privacy, confidentiality, and the amount of time required for one-on-one coaching.

The primary reason for implementing FFD practices is a desire on the part of the carrier to be proactive in improving driver safety and quality of life. Benefits are also expected to improve carrier operations. One carrier has noted that his company began using an FMP as a result of frequently having early-morning rollovers, a trend their FMP has erased entirely. Carriers report that their programs meet goals and expectations, and the results generally pay for themselves. The return on investment (ROI) associated with FFD practices can be quantified, with the highest ROIs associated with smoking cessation programs, weight-loss programs, and sleep apnea treatment. According to the carriers interviewed, these programs substantially reduce medical insurance (particularly related to heart attacks and strokes) and workers' compensation costs, reduce fatigue-related accidents and injuries, and improve driver retention. In addition, most companies reported happier, more energetic, and more productive drivers, noting that FMPs and health and wellness programs are an effective way of demonstrating that drivers are cared for outside of just the service they are providing.

The drivers interviewed in this case study confirm reports of positive outcomes from participating in FFD activities. They appreciate their carriers for creating programs designed for their personal benefit. One driver commented, "Treating me right makes me want to stay [with my employer] because they care about me as a person and care about my family," corroborating reports that FFD practices foster better relationships between workers and employers and reduce turnover.

Improving driver retention is especially important in an industry known for traditionally high levels of turnover (Watson, 2011). Concerning FFD, the best practices that have been outlined confirm the importance of a stable workforce in promoting positive behaviors and achieving desired safety outcomes. For instance, carriers stress the importance of open lines of communication among drivers, dispatchers, and management, something that comes from getting to know drivers over the years, which makes it difficult for companies that have a low retention rate. The study also reveals the importance of employing experienced drivers—experience is the only thing that helps drivers get better at handling work-life balance, knowing personal limitations, and making appropriate choices or decisions.

Participation in FFD programs varied among interviewees and types of programs. To improve participation, it is recommended that drivers first be informed of what the carrier offers with regard to FFD, understand the benefits of participation, and recognize that other drivers are participating (as the single biggest influence on participation is peer pressure). Participants must also be continually reminded that benefits are long term and should not be expected to occur overnight. Interactive approaches to FFD (e.g., health screenings or fitness centers) were considered to be more effective than passive approaches (e.g., distributing literature).

Action Items

The following action items are recommended:

- Educate employees at all levels of a company how to identify, prevent, and combat driver fatigue:
  - Interact with drivers prior to each shift (to the extent possible);
  - Screen for, diagnose, and treat sleep disorders;
  - Look for patterns of behavior indicative of fatigue or distraction (e.g., unintentional lane changes, progressively declining speeds, or hard braking);
  - Use EOBRs to ensure compliance with HOS regulations; and
  - Teach drivers how to manage free time and obtain sufficient rest.
- Establish health and wellness goals and inform drivers of the resources available to them for reaching these goals:
  - Make health screenings a priority to identify drivers who have problems with heart disease, diabetes, hypertension, or sleep disorders;
  - Establish a smoking cessation program;
  - Increase awareness of healthy eating habits and make healthy snacks available during meetings; and
  - Provide opportunities and encouragement for exercise and weight loss.
- Find optimal schedules that are customized for each individual driver and try to keep them as consistent as possible.
- Provide a resource for driver family members to use in lieu of interrupting the driver while he or she is on duty.
- Obtain buy-in and align goals with driver families to ensure that there is 24/7 progress.

CHAPTER 7

Conclusions and Recommendations

The objectives of this research project are to identify the root driver-related factors that contribute to cargo tank truck rollovers and to determine the best safety, management, and communication practices that can be employed by carriers to eliminate or minimize driver errors.

7.1 Root Driver-Related Factors

Authoritative sources of information such as the MCMIS, HMIRS, and TIFA crash databases do not yield enough information to identify the root factors absolutely and conclusively. Fortunately, the separate analyses of TIFA and police accident reports (PARs) conducted by the research team did yield correlations in potential driver-related root factors.

Driver-related causes are leading factors in cargo tank truck rollovers. These causes lead to the unsafe acts that directly lead to rollovers. The unsafe acts that are most frequently identified through the PAR analysis are

- Driving too fast for conditions,
- Illegal maneuver or improper turning,
- Inadequate evasive action, and
- Poor directional control.

The most significant areas of potential driver-related contributing factors that lead to these unsafe acts include

- Information gathering,
- Driver state,
- Physiological condition,
- Obesity and health,
- Alcohol or drug involvement, and
- Vehicle control.

A number of these driver-related factors relate to, or contribute to, the others. Certainly any of the first five areas can result in poor vehicle control, as well as alcohol or drug involvement being considered a characteristic of driver state. Driver state, in turn, can be a factor in, but not the sole causal factor of, inadequate information gathering.

Inadequate information gathering is identified as the chief contributing factor, accounting for 72% of identified contributing factors. *Information gathering* includes such characteristics as distraction, poor situational awareness, failure to recognize a hazard, and inadequate visual surveillance—in short, instances of not paying attention. *Driver state* accounts for 19% of identified contributing factors and includes such characteristics as impairment (e.g., alcohol, drugs, or medications), aggressive behavior, drowsiness, being asleep, or having limited capacity—in short, not being fit for duty or in the proper state of mind at the time of the crash.

The analysis of the TIFA data showed that driver-related factors such as alcohol and drug involvement, obesity, and health are far more prevalent in single-vehicle crashes than in multiple-vehicle crashes. Although TIFA, MCMIS, and HMIRS were of some use to the project, these databases do not point to definitive root causes. This was a key conclusion of *HMCRP Report 1: Hazardous Materials Transportation Incident Data for Root Cause Analysis,* and the conclusion was validated in this research project. The most accurate method for determining driver-related root causes would require the type of detailed analysis performed by insurance companies and carriers following major crashes or the effort that was conducted for the Large Truck Crash Causation Study, or LTCCS (FMCSA, 2006).

Cargo tank truck operators (i.e., carrier or trucking company officials) do influence how drivers behave and do influence the drivers' state of mind at the time they are faced with a threatening situation. For each of the contributing factors identified, operators can exert influence through programs and practices they put in place. These include

- Fitness-for-duty,
- Health awareness,
- Safety culture,

- Hiring,
- Training,
- Scheduling and dispatch, and
- Operations.

While safety culture is the key ingredient (in the absence of which any of the other influencers can have only a modest impact, at best), no one practice or program is sufficient on its own to effectively influence driver behavior and reduce rollovers.

7.2 Best Safety Practices for Drivers and Carriers

The second objective for this research was to determine best safety, management, and communication practices that can be used to minimize or eliminate driver errors in cargo tank truck operations. Common practices emerged from the extensive interviews with cargo tank carriers and with other industries. An interested manager should read the model safety program in Section 6.1.4 and see if any of its ideas can be implemented as a first step.

Appendices D through J of this report are resources to help carriers implement the best safety, management, and communication practices. Appendices are not included herein, but are published online at www.TRB.org by searching for HMCRP Report 7. Appendices D through J are as follows:

- *Appendix D: Case Study 1—Outline of an Overall Safety Program.* Section 6.1.4 is an extended discussion of an overall safety program. This appendix presents similar material in checklist form.
- *Appendix E: Case Study 1—Investigation Report for a Fictitious Rollover.* The purpose of an investigation is to avoid a repeat. Finding all the dominoes that led to the problem and fixing them can be a great benefit. This example shows what kinds of questions might be asked. Guidelines for conducting the investigation are in Section 6.1.5.
- *Appendix F: Case Study 2—Sample Driver Check Ride Evaluation Form.*
- *Appendix G: Case Study 2—Sample Ride-Along Driver Observation Form.* The safety manager can print one of these checklists and bring it on the next ride. The first form is shorter and lists a number of skills. The second, longer form lists actions to be observed.
- *Appendix H: Case Study 2—Performance Dashboard Reporting.* A busy terminal manager can review the performance dashboards to see how industry leading carriers measure and report performance.
- *Appendix I: Case Study 2—Questions to Ask in Selection of In-cab Camera Systems.* Many carriers have found in-cab cameras to be a valuable tool for coaching drivers and defending lawsuits. Here are questions to ask in selecting a system.
- *Appendix J: Case Study 3—Fatigue Management Program Guideline and Scoring Worksheet.* This worksheet is patterned after one from a Transport Canada (2011) study on rail safety. It lists program components and a basis for measuring progress toward instituting a mature fatigue management program.

The selection, implementation, and assimilation of a behavior-based safety program can be a long and evolving process. An objective comparison of the existing operation and incident record can shed light on where to focus initial efforts. Certain practices can be adopted or enhanced in short order. Many of the identified good practices can be initiated in parallel or in phases. Improvement will not come overnight. Whether an organization is large or small, the inertia of the organization will tend to resist sudden changes.

All contributors agree that to be successful, the safety culture must be an umbrella over all operational activities and that the safety program must be visible at all levels of the organization and conducted with integrity. While the driver is typically the only occupant in the cab, the safe operation of the fleet is a collaborative effort of the entire organization, as well as the driver's family.

The VicRoads Heavy Vehicle Rollover Prevention Program is a comprehensive package. Elements of it can be implemented in the cargo tank truck industry right away. The videos and other program materials are available for download, and a wooden model for shared use is in North America. With effort, the program can be made more relevant and more specific to North American cargo tank vehicles and practices. Tank carriers and others in the industry should continue to work together to develop new ways to present the safety message to maintain the attention of drivers through their entire career.

Any carrier of more than two people can have managers riding with drivers to watch daily habits and practices. A carrier of any size can develop an atmosphere of trust and the shared goal of everyone's safety. Larger carriers with significant corporate resources can implement an automated electronic program to track the statistics of drivers, but even a small carrier can follow the example of plotting CSA scores with a pencil and paper. All carriers should understand the CSA program and how it can be used to improve performance. FMCSA's website provides useful information on CSA and the Safety Measurement System (SMS). Useful links include the following:

- CSA homepage: http://csa.fmcsa.dot.gov/default.aspx,
- Carrier SMS results: http://ai.fmcsa.dot.gov/sms/,
- Frequently asked questions: http://csa.fmcsa.dot.gov/FAQs.aspx, and
- Motor Carrier Tool Kit: http://csa.fmcsa.dot.gov/resources.aspx.

FMCSA also provides a Pre-Employment Screening Program. It is available to potential employers for pre-screening with the written consent of the driver. The program is voluntary and not part of CSA. Information is not available to the carrier for currently employed drivers. Additional information can be found at www.psp.fmcsa.dot.gov/pages/FAQ.aspx.

Health and wellness programs and education, fatigue management programs, and scheduling and dispatch practices that proactively focus on safety are key components of successful fitness-for-duty processes. Carriers who were interviewed see fitness for duty as a team effort involving the company, the driver, and the driver's family.

This report aims to provide tools that operators can implement right away, both to see near-term results and to continue the evolving safety process over the long term. Management teams can review the lessons learned and can adopt or modify ideas on components of their safety program and culture, including how to incorporate driver families onto the safety team.

7.3 Recommendations for Future Work

In the near future, the industry will have access to a tremendous amount of data on driver practices that can be correlated with rollover rate. As FMCSA rolls out CSA, its behavior analysis and safety improvement categories (BASIC) measures will be tracked. Larger carriers have developed or are developing extensive databases of on-road events that, over time, can be correlated with rates of rollovers and other incidents. As initial experience is gained, the practices of early adopters can be disseminated as examples for other carriers.

Complete information for a thorough root-cause analysis is best obtained by thorough investigation. It remains cost-prohibitive to conduct such analysis under the public sector purview for each rollover. Carriers and insurance companies hold the most complete set of information for this analysis, but business reasons prohibit their information being released into the public domain. A process that would allow for root causes at an aggregate level to be obtained, that would allow for valuable lessons to be shared to improve safety across the industry, and that would provide legal protection and ensure confidentiality to those providing the data is likely the most effective solution to root-cause identification of driver-related factors in cargo tank truck rollovers.

A detailed analysis of rollover incidents, similar to the LTCCS (FMCSA, 2006) would add valuable information that can benefit the cargo tank truck industry in its efforts to reduce rollovers. This project's root-cause analysis did show that it might be worthwhile to study one subset of cargo tank rollover crashes—those involving single vehicles. Several of the driver factors associated with these crashes are over-represented when compared with multiple-vehicle crashes.

All motor carriers interviewed were pleased with their behavior management practices, including the onboard technology systems when applicable. There was some concern, however, with the number of products that it takes to measure all metrics of interest, and carriers wished that more functions could be integrated into a single system. A carrier that wants to count hard braking incidents, record in-cab video, establish geofencing, and study electronic stability interventions may be dealing with three vendors and three separate cell communications systems. Often, these systems may not be integrated. Either the marketplace, a concerted industry-wide effort, or both eventually will lead to more-integrated and easy-to-use products.

Organizations such as National Tank Truck Carriers and ATA provide vehicles to share best practices and educate the industry. FMCSA has also made strong contributions to improve safety through education. A VicRoads program can be an effective supplement to existing training programs and videos available to the industry. This would best be facilitated by a not-for-profit or industry association.

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Glossary

AFM	Advanced fatigue management
ATA	American Trucking Associations
ATC	Australian Transport Council
ATRI	American Transportation Research Institute
BASICs	Behavior Analysis and Safety Improvement Categories
BBS	Behavior-based safety
BFM	Basic fatigue management
BMI	Body mass index
CB	Citizen's band
CMV	Commercial motor vehicle
CSA	Compliance, Safety, Accountability
CSMS	Carrier Safety Measurement System
CTBSSP	Commercial Truck and Bus Safety Synthesis Program
DSMS	Driver Safety Measurement System
EOBR	Electronic onboard recorder
ESC	Electronic stability control
FARS	Fatality Analysis Reporting System
FFD	Fitness for duty
FMCSA	Federal Motor Carrier Safety Administration
FMCSR	Federal Motor Carrier Safety Regulation
FMP	Fatigue management program
FMT	Fatigue management technology
FPS	Frames per second
GPS	Global positioning system
GYR	Green, yellow, red
HMCRP	Hazardous Materials Cooperative Research Program
HMIRS	Hazardous Materials Information Resource System
HOS	Hours of service

LDWS	Lane Departure Warning System
LED	Light-emitting diode
LTCCS	Large Truck Crash Causation Study
MCMIS	Motor Carrier Management Information System
NAFMP	North American Fatigue Management Program
NHTSA	National Highway Traffic Safety Administration
NHVAS	National Heavy Vehicle Accreditation Scheme
NTSB	National Transportation Safety Board
O-O	Owner-operator
OBC	Onboard computer
OBSM	Onboard safety monitors
OEM	Original equipment manufacturer
OSS	Onboard safety system
OTC	Over the counter
PAR	Police accident report
PHMSA	Pipeline and Hazardous Materials Safety Administration
PU	Power unit
PVT	Psychomotor vigilance test
RI	Roadside inspection
ROI	Return on investment
RPM	Revolutions per minute
RSC	Roll stability control
SMS	Safety Measurement System
TIFA	Trucks involved in fatal accidents
TRB	Transportation Research Board
UFOV	Useful field of vision
UMTRI	University of Michigan Transportation Research Institute
U.S.DOT	U.S. Department of Transportation
VHF	Very high frequency

Appendices

The following appendices can be found online at www.TRB.org by searching for HMCRP Report 7:

- Appendix A: Police Accident Reports Annotation Table
- Appendix B: Detailed Findings from TIFA on Rollover Causes
- Appendix C: Interview Questions
- Appendix D: Case Study 1—Outline of an Overall Safety Program
- Appendix E: Case Study 1—Investigation Report for a Fictitious Rollover
- Appendix F: Case Study 2—Sample Driver Check Ride Evaluation Form
- Appendix G: Case Study 2—Sample Ride-Along Driver Observation Form
- Appendix H: Case Study 2—Performance Dashboard Reporting
- Appendix I: Case Study 2—Questions to Ask in Selection of In-cab Camera Systems
- Appendix J: Case Study 3—Fatigue Management Program Guideline and Scoring Worksheet

Abbreviations and acronyms used without definitions in TRB publications:

AAAE	American Association of Airport Executives
AASHO	American Association of State Highway Officials
AASHTO	American Association of State Highway and Transportation Officials
ACI–NA	Airports Council International–North America
ACRP	Airport Cooperative Research Program
ADA	Americans with Disabilities Act
APTA	American Public Transportation Association
ASCE	American Society of Civil Engineers
ASME	American Society of Mechanical Engineers
ASTM	American Society for Testing and Materials
ATA	American Trucking Associations
CTAA	Community Transportation Association of America
CTBSSP	Commercial Truck and Bus Safety Synthesis Program
DHS	Department of Homeland Security
DOE	Department of Energy
EPA	Environmental Protection Agency
FAA	Federal Aviation Administration
FHWA	Federal Highway Administration
FMCSA	Federal Motor Carrier Safety Administration
FRA	Federal Railroad Administration
FTA	Federal Transit Administration
HMCRP	Hazardous Materials Cooperative Research Program
IEEE	Institute of Electrical and Electronics Engineers
ISTEA	Intermodal Surface Transportation Efficiency Act of 1991
ITE	Institute of Transportation Engineers
NASA	National Aeronautics and Space Administration
NASAO	National Association of State Aviation Officials
NCFRP	National Cooperative Freight Research Program
NCHRP	National Cooperative Highway Research Program
NHTSA	National Highway Traffic Safety Administration
NTSB	National Transportation Safety Board
PHMSA	Pipeline and Hazardous Materials Safety Administration
RITA	Research and Innovative Technology Administration
SAE	Society of Automotive Engineers
SAFETEA-LU	Safe, Accountable, Flexible, Efficient Transportation Equity Act: A Legacy for Users (2005)
TCRP	Transit Cooperative Research Program
TEA-21	Transportation Equity Act for the 21st Century (1998)
TRB	Transportation Research Board
TSA	Transportation Security Administration
U.S.DOT	United States Department of Transportation