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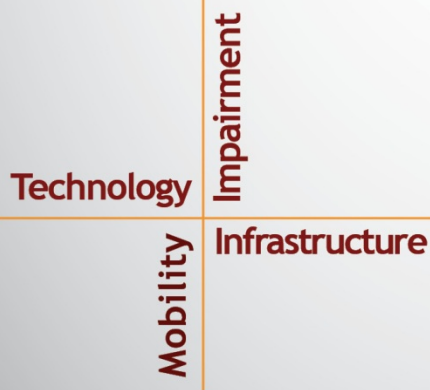
National Surface Transportation
Safety Center for Excellence

Effective Strategies to Improve Safety

Case Studies of Commercial Motor Carrier
Safety Advancement

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EXECUTIVE SUMMARY

Previous research has identified a number of safety improvement strategies that commercial motor vehicle (CMV) fleets can use to reduce crashes. These include using strict initial hiring guidelines to identify safe drivers, creating comprehensive training programs for newly hired drivers, designing comprehensive training programs for experienced drivers, building a strong safety culture, improving driver scheduling to reduce risky driving and fatigue, equipping trucks with advanced safety technologies, and implementing proactive vehicle maintenance programs.

Although previous research has documented safety improvement strategies, many carriers may not have real-world data and/or information on the strategies that other carriers have successfully used to improve safety. Thus, carriers in search of suggestions may find an overview of other carriers' success stories useful in developing their own safety improvement plans.

OBJECTIVE

This study identified strategies that CMV fleets have successfully used to improve their safety outcomes. Specifically, this study answered the following three questions:

1. What safety interventions did CMV carriers successfully use to significantly improve safety outcomes?
2. What safety interventions were not effective in significantly improving safety outcomes?
3. What were the barriers in implementing each safety intervention, and how were those barriers overcome?

METHOD

The research team worked with CMV insurers and state trucking associations to identify nine CMV carriers that successfully improved safety outcomes, which the research team verified. Safety improvements involved Federal Motor Carrier Safety Administration-reportable crashes, less severe crashes, insurance claims, and/or Compliance, Safety, and Accountability (CSA) Behavior Analysis and Safety Improvement Category (BASIC) scores. Following these verifications, the research team recruited the nine carriers to participate in an hour-long interview to document the strategies they used to improve their safety outcomes. Following the nine interviews, the research team performed a content analysis to complete an expanded Haddon Matrix of the carriers' successful strategies.

RESULTS

The following table provides the safety improvements across each of the carriers.

Carrier	Safety Improvement	Top Strategies
A	<ol style="list-style-type: none"> 19.5% reduction in FMCSA-reportable crash rate 20 percentile improvement in CSA Crash Indicator BASIC 56% reduction in preventable, rear-end collisions 	<ol style="list-style-type: none"> Comprehensive ongoing driver training program Automatic emergency braking (AEB)
B	<ol style="list-style-type: none"> 31.7% reduction in FMCSA-reportable crash rate 70 percentile improvement in CSA Crash Indicator BASIC 49 percentile improvement in CSA Unsafe Driving BASIC 	<ol style="list-style-type: none"> Video-based onboard safety monitoring (OSM) system paired with a data-driven driver coaching AEB, and lane departure warning (LDW) Strict driver hiring criteria
C	<ol style="list-style-type: none"> 75.6% reduction in preventable crashes 17 percentile improvement in CSA Unsafe Driving BASIC 	<ol style="list-style-type: none"> Develop a strong safety culture
D	<ol style="list-style-type: none"> 45 percentile improvement in CSA Unsafe Driving BASIC 24 percentile improvement in CSA Maintenance BASIC 70 percentile improvement in CSA Hours-of-Service (HOS) BASIC Eliminated all preventable rear-end crashes and rollovers 	<ol style="list-style-type: none"> Develop a strong safety culture Collision mitigation technologies including AEB, LDW, roll stability control (RSC), and video-based onboard safety monitoring (OSM) systems
E	<ol style="list-style-type: none"> 35.8% reduction in FMCSA-reportable crashes (10% reduction in 2018 alone) 	<ol style="list-style-type: none"> Develop a strong safety culture Collision mitigation technologies including AEB, LDW, and video-based OSM systems
F	<ol style="list-style-type: none"> 66.3% reduction in FMCSA-reportable crash rate 44 percentile improvement in CSA Crash Indicator BASIC 	<ol style="list-style-type: none"> Develop a strong safety culture Strict driver hiring criteria
G	<ol style="list-style-type: none"> 26.3% reduction in FMCSA-reportable crashes since 2012 66.3% reduction in FMCSA-reportable crash rate from 2017 to 2018 38 percentile improvement in CSA Crash Indicator BASIC since 2016 	<ol style="list-style-type: none"> Video-based OSM systems AEB Electronic logging devices (ELDs)
H	<ol style="list-style-type: none"> 24.4% reduction in FMCSA-reportable crash rate 39.7 percentile improvement in CSA Crash Indicator BASIC since 2014 	<ol style="list-style-type: none"> Strict driver hiring criteria Develop a strong safety culture
I	<ol style="list-style-type: none"> 53.6% reduction in all incidents Zero FMCSA-reportable crashes 46 percentile improvement in CSA HOS BASIC score 	<ol style="list-style-type: none"> Develop a strong safety culture Video-based OSM systems

- 1.
2. The table below displays an expanded Haddon Matrix with the combined effective strategies used by the participating carriers.

	Vehicle	People	Environment	Management Culture
Pre-crash	<ul style="list-style-type: none"> • AEB • LDW • Blind spot detection • Stability control systems • Speedgauge • Speed limiters • Video-based OSM systems • Monitor wear and tear • Replace parts when issues arise • 24 hour a day maintenance shop • Service tractors before 10,000 miles • Service trailers every 30 days • Inspect truck and trailer each time it returns to facility • Load specific pre-trip checklists 	<ul style="list-style-type: none"> • Participant in FMCSA's pre-employment screening program (PSP) • Require previous driving experience • On-the-job training for all drivers • Finishing program for new drivers • New hire mentoring • Face-to-face interview • Hiring criteria for involvement in previous crashes • Hiring criteria for previous citations and inspections • Past employer referrals • Driver referrals • Driving simulator assessment • Driving simulator training • Online training • Hair drug testing • Physical fitness/agility test • Safety pledge • Monthly or quarterly in-person safety meetings • Coaching sessions based on OSM data 	<ul style="list-style-type: none"> • Visible safety pledge signage in terminals • Plan routes for 45 mph average • Mandatory stops in bad weather • Schedule routes based on individual sleep patterns • Monitoring driving time in real-time 	<ul style="list-style-type: none"> • Non-monetary safety awards • Monetary safety bonuses • Frequency safety communication • Positive, non-confrontational coaching sessions • Open door policy • Full-time trainers to maintain consistent safety message • Management buy-in to safety programs • Zero tolerance for HOS violations • Ownership/top management safety communication • Driver scorecards • Family events • Encourage family involvement in safety • Family culture • Progressive discipline policy • Internal and external safety benchmarking • Share key carrier-wide crash and incident data with drivers • Share carrier-wide safety cost data with drivers • Accountability for safety in all departments • Wellness checks on drivers • Educating all department on their impact on safety • Health and wellness program • Drivers collaborate to develop safety strategies
At scene				<ul style="list-style-type: none"> • Support driver at scene
Post-crash	<ul style="list-style-type: none"> • Vehicle repair or replacement 	<ul style="list-style-type: none"> • Post-incident one-on-training • Progressive discipline policy based on crash causes • Health and wellness checks 		<ul style="list-style-type: none"> • Use of video-based OSM to find identify objective data on crash causes • Use of video-based OSM data for driver exonerations • Internal tracking of crashes for data analysis • Internal and external benchmarking • Driver incident reporting system

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LIST OF ABBREVIATIONS AND SYMBOLS

AEB	automatic emergency braking
ACC	adaptive cruise control
ASA	active steering assist
BASIC	Behavior Analysis and Safety Improvement Category
BSW	blind spot warning
CDL	commercial driver's license
CMV	commercial motor vehicle
CSA	Compliance, Safety, Accountability
DOT	Department of Transportation
ESC	electronic stability control
FH	for hire
FMCSA	Federal Motor Carrier Safety Administration
HOS	hours-of-service
LDW	lane departure warning
LTL	less-than-truckload
MVR	motor vehicle record
OSM	onboard safety monitoring
PSP	pre-employment screening program
RIPB	risk-informed performance-based
ROI	return on investment
RSC	roll stability control
SL	speed limiters
TL	truckload

CHAPTER 1. INTRODUCTION

In 2018, the Federal Motor Carrier Safety Administration (FMCSA) identified 2,864 high-risk commercial motor vehicle (CMV) carriers.⁽¹⁾ A high-risk, non-passenger carrier is defined as having two or more scores in Behavioral Analysis and Safety Improvement Categories (BASICS) at or above the 90th percentile for 2 consecutive years and at which an onsite investigation has not occurred in the previous 18 months. In addition to these high-risk carriers, there are likely thousands of additional carriers each year whose insurance providers or internal safety audits have identified unsatisfactory safety records.

FMCSA and carrier insurers target these high-risk CMV carriers (and carriers with unsatisfactory safety records) for safety interventions. These interventions may include a warning letter from FMCSA and/or their insurance provider, an offsite or onsite safety investigation, and the development of a safety improvement plan to address safety problems. The safety improvement plan may detail practices the carrier should adopt to improve safety performance, such as improved driver selection and management practices, revised drug and alcohol testing protocols, the implementation of new vehicle safety technologies, improved vehicle maintenance, the development of a fatigue management program, improved post-crash investigations, etc. The purpose of this safety improvement plan is to serve as a roadmap to significantly improve safety outcomes. However, many carriers may be unaware of information about and data on strategies that other CMV carriers have used to successfully advance safety outcomes. These carriers may find a best practice guide or an overview of other carriers' success stories useful when developing their safety improvement plans.

OBJECTIVE

The current study conducted in-depth case studies of CMV fleets that significantly improved their safety outcomes. Specifically, this study answered the following research questions:

1. What safety interventions did CMV carriers successfully use to significantly improve safety outcomes?
2. What safety interventions were not effective in significantly improving safety outcomes?
3. What were the barriers in implementing each safety intervention, and how were those barriers overcome?

CHAPTER 2. LITERATURE REVIEW

Research investigating potential CMV safety countermeasures varies widely. However, most of the successful or promising countermeasures target one of the following important safety issues: at-risk driving behaviors (including aggressive driving), high risk drivers, lifestyle and general health and wellness problems, a lack of common defensive driving skills, delays associated with loading and/or unloading, and fatigue/drowsiness.⁽²⁾ The following broad categories of effective strategies address these important safety issues:

- Driver hiring policies and programs
- Driver training policies and programs
- Organizational safety culture and programs to encourage safe driving and discourage unsafe driving
- Dispatching and scheduling policies
- Technologies to improve safety
- Vehicle maintenance programs

The remainder of this chapter provides a high-level overview of each of the strategies. For detailed descriptions, please see the specific references.

DRIVING HIRING STRATEGIES TO IMPROVE SAFETY

One of the most effective ways to improve CMV safety is to hire safe drivers. Research indicates the best way to hire the safest drivers is to prioritize an applicant's driving record, considering such factors as involvement in previous crashes and receiving violations.^(2,3) In addition, selecting new hires based on driving experience, demographics (e.g., age), training, previous employer recommendations, and personality factors are recommended to identify and hire safe drivers.⁽³⁾

In 2010, the FMCSA developed the CMV Pre-Employment Screening Program (PSP).⁽⁴⁾ This program was designed to assist CMV carriers screen driver applicants based on previous crash and inspection data. The PSP provides the CMV up to 5 years of crash and three years of inspection data for all driver applicants. FMCSA found that carriers who used the PSP had an 8% lower crash rate and a 17% lower out-of-service rate compared to CMV fleets who did not use the PSP.⁽⁴⁾

In a synthesis of carrier best practices, researchers recommend carriers use the following systematic hiring program to identify "high risk" drivers.⁽⁵⁾

1. Increase advertising for open positions. This increases the pool of drivers applying for the open position, which will likely increase the pool of safe drivers. An increased applicant pool can allow a carrier to be more selective for safety. Additionally, carriers should include minimum qualifications and information on the attractiveness of the position in job announcements. Stock⁽⁶⁾ recommends using a minimum of 2 years driver experience if possible.

2. Use a comprehensive application that asks questions related to all minimum qualifications, including detailed information on previous driving employment with contact information. Carriers should do mandatory checks with the most recent job and follow-up with all driving jobs within the past 10 years. Also, part of the application should be a review of the applicant's motor vehicle record (MVR) and a background check. Stock⁽⁶⁾ recommends only hiring drivers with less than six total points on their MVR, no more than one crash, or three violations within the previous 3 years. Additionally, the initial driver screening should include FMCSA's PSP.
3. Based on the applications received, select drivers for an in-person interview. Carriers should structure these interviews so that all applicants receive a standard set of questions and may include validated selection tests. Stock⁽⁶⁾ recommends that several individuals within the fleet interview each driver. These individuals may include someone from the human resources department, a safety manager, a driver manager, a maintenance manager, and/or an experienced and well-respected driver. Additionally, drivers should go through the Department of Transportation (DOT) physical exam; a well administered road test to include inspection requirements, vehicle maneuvers, and assessment of defensive driving skills; and alcohol and drug tests.
4. Hire applicants based on successfully passing each of the tests.

TRAINING POLICIES AND PROGRAMS FOR NEW AND EXPERIENCED DRIVERS

Although hiring may be a carrier's first way to ensure safety, driver training is also critical. Internal personnel often conduct driver training; however, other training methods are available. For example, some carriers offer web-based educational modules and/or driving simulators to review specific safety information. Still others hire outside training consultants to teach drivers.

Overall, carriers often design trainings to target two different types of drivers: new hires and existing drivers.

Trainings for New Hires

Carriers usually use new hire orientation to introduce their safety culture to new employees. New drivers are typically introduced to a carrier's specific policies related to safety during orientation. Such policies may include elements such as requirements for pre- and post-trip inspections; an overview of the carrier's safety programs, technologies, and disciplinary procedures; a review of the hours-of-service (HOS) regulations; and what to do if the driver is involved in a crash.⁽³⁾ Other training topics may include defensive driving techniques, driver health and wellness programs, and fatigue management.⁽⁶⁾

While driver orientation provides a good opportunity to introduce new drivers to company policies and programs related to safety, research indicates that behind-the-wheel/on-the-job training is an effective method to ensure drivers have the skills necessary to be safe.^(3,5,6) Depending on the new driver's experience, this training may consist of several months of working with a mentor driver.^(5,6) This period of training may include ride-alongs or team driving with the mentor driver.

Trainings for Existing Drivers

Not only is it important to train new hires, it is equally important to periodically provide education and training to experienced drivers. This provides drivers with continuous learning opportunities and can address any safety areas where drivers may have become lax.⁽⁶⁾ To help identify drivers in need of refresher training, research suggests conducting periodic driver performance evaluations for all drivers. This includes regularly scheduled MVR checks and the monitoring of incident data for trends indicating increased involvement in minor incidents or cargo damage. Another method for regular driver evaluations is via driver observations. Carriers accomplish driver observations through ride-alongs, peer observation by co-drivers, covert following, or with the use of an onboard safety monitoring (OSM) system.⁽⁵⁾ Using data from the OSM, carriers can identify specific behaviors and training needs for each individual driver.

Research on behavior-based safety management techniques documents additional training opportunities, such as those identified by Hickman et al.,⁽⁷⁾ who found the following behavior-based management strategies to be effective (in order of effectiveness):

- Training and education on specific driving behaviors
- Peer observation of safe and unsafe driving
- Peer feedback for areas of improvements and demonstration of safe behavior
- Disincentives/punishment for unsafe driving
- Training and education on non-specific driving behaviors
- Incentives to encourage safe driving
- Prompts to remind driver to perform safety-related behaviors and tasks
- Safety self-management

ORGANIZATIONAL SAFETY CULTURE AND PROGRAMS TO ENCOURAGE SAFE DRIVING AND DISCOURAGE UNSAFE DRIVING

Research has shown the connection between organizational safety culture and a carrier's actual safety performance.⁽⁸⁾ Bergoffen et al. indicated that a fleet's safety culture is highly related to the success of their safety program.⁽⁹⁾ Additionally, Corsi and Barnard found a strong link between safe carriers and safety culture.⁽³⁾ The safest companies had strong safety cultures where safety was valued, costs were not a factor when making safety decisions, employees were comfortable raising safety concerns, and all employees "bought-in" to the safety process.

Demonstrating Management Commitment to Safety

Dedication and commitment from the top of the organization are key when creating a strong safety culture.⁽⁶⁾ Two methods that top management can employ to demonstrate a commitment to safety are conducting regular safety meetings and maintaining regular communication where safety is the main topic. This regular communication reinforces the belief that safety is a core value. Managers, safety department personnel, drivers, maintenance, dispatchers, and administration workers should attend regular safety meetings. During these meetings, management should discuss defensive driving tips, regulations, crash investigation, and seasonal driving topics. Additionally, these meetings provide a good opportunity to share video examples

captured from OSM devices (if the trucks are equipped) and for external speakers, such as law enforcement, insurance representatives, or government representatives to discuss timely topics.

In addition to demonstrating top management support through regular safety meetings, the following necessary steps (in no particular order) have been identified as best practices for carriers to employ when attempting to improve their safety culture:^(9,10)

- Provide safety training and education to all employees in the organizations (not just drivers)
- Provide incentives and rewards as motivators to perform safe behaviors
- Move away from “accident” and towards “crash,” “collision,” or “incident”
- Create clear and easy to understand policies and procedures
- Move away from a “gotcha” mentality during crash investigation and instead focus on identifying how the driver can improve
- Introduce drivers immediately to the strong safety culture during orientation in order to help create driver accountability
- Maintain an open door policy to discuss safety-related issues

Safety Benchmarking

Safety benchmarking is an important step when developing a strong safety culture.⁽⁹⁾ Safety benchmarking allows the CMV fleet to identify what is working well and what is not working as well as expected. There are two types of safety benchmarking: internal and external. Internal benchmarking involves comparing current programs and policies to programs and policies that should be required. Additionally, internal benchmarking can compare current crash and violations statistics with goal crash and violation statistics. External benchmarking is similar; however, CMV fleets compare internal safety programs, policies, and performance with industry best practices.

Incentive/Reward Programs to Encourage Safe Driving

Proactively encouraging safe driving with incentive and reward programs is an effective way to improve a CMV fleet’s safety culture.^(3,7) Some of these programs include individual and/or group rewards for safe performance. Carriers may base these rewards on crashes, violations, or convictions over a specific period of time or crash/violation-free miles. These rewards do not need to be financial; they may include verbal praise, public recognition inside and/or outside the company, management congratulation letters, safety celebrations, and/or merchandise.

Although rewards are critical in developing a strong safety culture, well-documented discipline policies are equally important.⁽³⁾ Often the most effective discipline policies focus on violating federal regulations, violating company policy, and unsafe driving. Usually the discipline progresses from verbal warnings to written warnings, followed by training, suspensions, and finally termination.

DISPATCHING AND SCHEDULING POLICIES

There are a number of ways that CMV fleets can use dispatching and scheduling to improve safety. Heitmann et al. conducted an operational test of a risk-informed performance-based (RIPB) safety system at a large CMV fleet in the U.S.⁽¹¹⁾ This carrier employed approximately 500 drivers in varying operations. This RIPB system involved training managers and dispatchers on the risks associated with certain schedules and included a feedback system to determine the relative risk of specific driver schedules/assignments. As part of the RIPB system, managers worked to reduce driver fatigue by changing start and end times, increasing rest breaks with two nights, minimizing night work, avoiding rotating start times, and reducing consecutive shifts. The RIPB system reduced driver schedules from six consecutive workdays with one day off to five consecutive workdays with one day off. Additionally, the percentage of drivers with dangerous fatigue risk scores dropped from 28.9% to 3.9% and those with relatively safe fatigue risk scores increased from 14.9% to 44.6%. There was a 23.5% reduction in crash rates, including a 55% reduction in severe crashes.

Knipling and Bergoffen identified a number of other scheduling best practices. These best practices included the following strategies:⁽¹²⁾

- Reduce loading/unloading/waiting times by implementing contracts with shippers/receivers
 - If a truck shows up on time, the shipper/receiver must load/unload within 2 hours
 - Detention fees are assessed if wait times are longer, and the fees are paid to the driver
- Maximize interstate and freeway travel and limit travel on local roads.
- Use schedules to reduce travel time during urban rush hours and other high-density traffic situations
- Avoid driving during adverse weather
- Avoid routing driver through construction zones as much as possible
- Schedule drivers on familiar routes
- Maximize day driving and avoid early morning schedule
- Encourage drivers to stop when tired and take a break

TECHNOLOGIES TO IMPROVE SAFETY

CMV fleets interested in reducing crashes can take advantage of a wide range of advanced safety technologies. Some of these technologies assume control of the vehicle via braking and/or steering, and some technologies only provide alerts. Some of the more common technologies include the following:

- Automatic emergency braking (AEB)
- Adaptive cruise control (ACC)
- Lane departure warning (LDW)
- Active steering assist (ASA)
- Blind spot warning (BSW)
- Roll stability control (RSC)

- Electronic stability control (ESC)
- Speed limiters (SL)
- Telematics
- Video-based onboard safety monitoring (OSM) systems

Advanced safety technologies are becoming an increasingly effective method to improve safety. On average, CMV fleets reported that technologies provide a 20% reduction in crashes and their costs.⁽¹³⁾ Furthermore, CMV fleets with low technology penetration had smaller crash reductions, and fleets with large technology penetration saw higher crash reductions. More recent research suggests some of the more common advanced safety technologies can provide even greater reductions. For example, Hickman et al. found that trucks equipped with LDW systems were involved in 47.8% fewer sideswipes and run-off-road crashes compared to trucks without LDW.⁽¹⁴⁾

Another common benefit of many advanced safety technologies is the data they generate.⁽¹³⁾ For example, driver/vehicle tracking systems have the added benefit of monitoring driver behavior. Many CMV fleets use these data for driver training and individual driver coaching. Additionally, CMV fleets report significant benefits related to ease of driver exonerations with the use of video-based OSM systems. Finally, behavioral data generated by many of these technologies can feed into driver scorecards.⁽¹²⁾ These scorecards provide drivers with feedback on their safety performance and compare their performance to other drivers within the fleet. CMV fleets often use these data in a fleet's incentive/reward program.

Although CMV fleets are realizing safety benefits with advanced safety technologies, there are several barriers to their implementation.⁽¹³⁾ The most important determining factor in the adoption of safety technologies was the return on investment (ROI). The majority of fleets (68%) surveyed by Belzowski et al. reported a positive ROI in 13–24 months,⁽¹³⁾ and Hickman et al. found a positive ROI for LDW and RSC.⁽¹⁴⁾ However, this information is not readily available across the industry. Since it is not readily available, many CMV fleets are skeptical of the positive ROI. Additionally, some of these technologies, such as driver monitoring systems, have the perception of being “big brother” systems, which can be a barrier to implementation.

VEHICLE MAINTENANCE PROGRAMS

Vehicle maintenance programs are a critical component of a CMV fleet's overall safety management system. These programs complement the driver-focused and management-focused programs by targeting the roadworthiness of the vehicles. Proactively targeting vehicle maintenance ensures all safety components on the trucks are in good working order and functioning properly. Proactive maintenance also helps reduce out-of-service rates. One of the best ways to keep trucks in good working order is through regularly scheduled maintenance. Previous research found that regularly scheduled maintenance and inspections were effective for preventative maintenance.^(2,9)

Corsi and Barnard developed best practices for vehicle maintenance to improve carrier safety.⁽³⁾ These best practices included the use of a computerized maintenance management program. This system ensures adherence to a regular maintenance schedule and helps with inventory management, labor, and budgeting. Another best practice is to outsource some of the

maintenance activity (mainly engine repairs and drive train repairs). Some CMV fleets find it easier to outsource these non-routine activities instead of hiring and maintaining a staff with this expertise. However, maintenance personnel can conduct more routine maintenance activities in-house. Finally, maintenance inspections should be scheduled frequently (e.g., every 10,000 miles), engine/drive trains should be overhauled after 700,000–800,000 miles, and regular trailer inspections should be scheduled before 10,000 miles.

CHAPTER 3. METHOD

The research team worked with two CMV insurance agencies and five state trucking associations in identifying eligible CMV fleets to participate in the study. Each eligible carrier experienced a significant reduction in crashes, insurance claims, or improvement in CSA scores. The research team confirmed the carriers' safety advancement by analyzing crash reductions found in the Motor Carrier Management Information System or in the carrier's internal incident dataset. Once the CMV fleets' safety improvements were confirmed, the research team contacted a representative from the selected fleet to recruit them to participate in the study. Nine CMV fleets participated in the study.

CASE STUDIES

The research team conducted in-depth case studies at the nine fleets. These case studies collected comprehensive information and data on CMV fleet safety interventions that resulted in improved safety outcomes. Specifically, the study focused on the safety countermeasures included in the Haddon Matrix.^(15,16) The Haddon Matrix described in Murray et al.⁽¹⁶⁾ includes pre-crash, crash, and post-crash factors associated with the following factors: carrier management culture, driver and managers, and trucks and equipment. Specifically, the case studies captured the following information:

1. Why did the carrier need to improve safety performance (including what initiated the need for improvement)?
2. What safety interventions, with details, did the CMV fleet adopt to improve fleet safety?
 - a. Improved driver selection and management practices
 - b. Revised driver training protocol
 - c. Implementation of new vehicle safety technologies
 - d. Improved vehicle maintenance
 - e. Improved scheduling and dispatch practices
3. What was the timeline for the implementation of safety interventions?
4. How were the safety interventions developed?
5. What steps did the CMV fleet take while implementing the safety interventions?
6. What were the pre- and post-intervention crash rates?
7. What measures assessed the effectiveness of the safety interventions?
8. Are the safety interventions still being used?

The research team collected information on these factors through interviews with carrier management knowledgeable about the carrier during the course of the safety interventions (see Appendix A). Detailed notes and/or audio recordings documented the qualitative data collected during the interviews.

CONTENT ANALYSIS

Following the interviews, a member of the research team performed a content analysis to identify key themes and subthemes. The content analysis approach used in this study was adapted from the framework analysis method.⁽¹⁷⁾ First, the research team transcribed all audio recordings from the interview. Second, a researcher read each of the transcriptions to become familiar with the

data set. Third, a researcher identified key strategies discussed during the interview. Finally, a researcher indexed and charted the key strategies into the Haddon Matrix.

CHAPTER 4. CASE STUDIES

As noted, nine CMV fleets participated in the case studies. Table 1 provides the demographic information for the participating carriers. The following subsections describe each of the CMV fleet case studies.

Table 1. Participating Carrier Demographics

CMV Fleet	Power Units	Drivers	Operation	Commodities	Fleet Type
A	>1000	>1000	Truckload (TL)	General freight, building materials, liquids/gases, chemicals, dry bulk, batteries	For hire (FH)
B	501–1000	500–1000	TL	General freight, metal, lumber, building materials, fresh produce, liquids/gases, meat, refrigerated foods, beverages	FH
C	501 –1000	500–1000	TL	General freight, building materials, paper products	FH
D	101–500	100–500	TL	General freight, metal, fresh produce, grains, meat, dry bulk, refrigerated food, beverages, paper products	FH
E	101–500	101–500	TL	General freight, household goods, building materials, fresh produce, meat, refrigerated foods, beverages, paper products	FH
F	51–100	51–100	TL	General freight, metal, motor vehicles, lumber/logs, building materials, machinery/large objects, grain, dry bulk, construction, and concrete products	FH
G	51–100	51–100	TL	General freight, livestock, refrigerated foods	FH
H	101–500	101–500	TL	General freight, household goods, fresh produce	FH
I	<50	<50	Less than Truckload (LTL)	Fresh produce, meat, refrigerated foods, frozen	FH

CARRIER A

Table 2 shows the period of time for Carrier A’s safety improvement, the safety outcomes that improved during the time period, and the magnitude of improvement.

Table 2. Carrier A Safety Improvement

Time Period for Safety Improvement	Safety Area Targeted	Objective Measure of Safety Improvement
2012–2018	<ol style="list-style-type: none">1. FMCSA-reportable crashes2. CSA Crash Indicator BASIC3. Preventable, rear-end collisions	<ol style="list-style-type: none">1. 19.5% reduction in FMCSA-reportable crash rate2. 20 percentile improvement in CSA Crash Indicator BASIC3. 56% reduction in preventable, rear-end collisions

Carrier A historically focused on the importance of safety. As part of this focus, the management team regularly conducted internal benchmarking to compare actual safety outcomes to safety goals. As a result, Carrier A’s top management decided to implement an advanced safety program in 2012. The implementation of this advanced safety program resulted in 19.5% fewer FMCSA-reportable crashes, a 20 percentile improvement in the CSA Crash Indicator BASIC, and a 56% reduction in preventable, rear-end collisions. The following subsections describe the specific programs that were included in Carrier A’s advanced safety program or that were believed to contribute to Carrier A’s improved safety outcomes.

Driver Hiring

Although revisions to Carrier A’s driver hiring policies were not included in the implementation of the advanced safety program in 2012, Carrier A believed these policies contributed to the safety improvements since 2012. To find the safest drivers, Carrier A used FMCSA’s pre-employment screening program (PSP) to prioritize drivers’ previous CMV driving history. Specifically, Carrier A used the PSP to identify patterns of safe or reckless driving. Using the PSP, Carrier A’s hiring criteria included the following:

- A minimum of 1 year CMV driving experience
- No more than three moving violations in the previous 3 years
- No more than one conviction of reckless driving or speeding greater than 15 mph

Historically, Carrier A required 3 years of CMV driving experience. However, in 2013 Carrier A reduced this requirement to 1 year of experience due to an increase in demand and a lack of driver applicants. Although the requirement for driving experience was lowered, Carrier A offset the potential increase in risk by implementing other safety measures, as discussed below.

Driver Training

In 2012, Carrier A implemented a proprietary driver-training program with the goal of improving safety and creating a consistent safety expectation and message for all drivers across all commodities. Due to Carrier A’s size, there was not consistent implementation of training from terminal to terminal. After recognizing inconsistencies in training, Carrier A took a top-down

approach during the program's creation process. Management analyzed current crash trends to target specific risks across the fleet and to identify skills that needed to be addressed by training. After the program was developed, a well-thought out communication plan was created to minimize challenges in implementation. This communication plan included management repeatedly introducing the training program to drivers and driver trainers across the fleet. Questions and concerns from drivers and driver trainers were discussed and Carrier A ensured that drivers were provided detailed information about why and how the training was developed.

The new safety-training program included two components. First, all new drivers were introduced to Carrier A's safety policies during an all-encompassing 2-hour safety training class. In this class, safety lessons focused on the rules of the road and strategies for preventing crashes. The second component included periodic refresher trainings and regular safety communication. Carrier A's safety department updated these refresher trainings annually to maintain drivers' interest and to address the previous year's crash trends. Additionally, all trainings and communication referred back to Carrier A's safety "buzz words." This helped Carrier A maintain a consistent safety message across the entire fleet and to connect back to the carrier's safety mission.

Organizational Safety Culture and Management Programs

As part of the new driver-training program, Carrier A hired a set of full-time driver trainers to travel across the country to deliver all in-person trainings. Carrier A implemented these trainers in an effort to bridge the gap between safety personnel and drivers. Having these trainers interact with every driver employed by Carrier A ensured all drivers received a consistent safety message and allowed the trainers to be a consistent face to Carrier A's safety culture. These trainers gave drivers someone to talk to who had significant experience behind the wheel.

In addition to using driver trainers to provide open communication to drivers and to gather feedback, Carrier A implemented a non-monetary safety reward program. Based on crash and violation free miles, Carrier A awarded pins, jackets, plaques, and recognition. Carrier A pilot tested the use of safety bonuses; however, data analyses found safety bonuses were not associated with improved safety. Thus, Carrier A only used non-monetary rewards in the 2012 advanced safety program.

Dispatching and Scheduling

Carrier A did not implement changes to dispatching or scheduling practices as part of the advanced safety program in 2012. However, Carrier A believed these practices were successful in maintaining a strong safety culture. Carrier A's dispatchers were trained to schedule routes based on an average 45 mph from pick-up to delivery on long-haul routes. In contrast, many fleets used an average of 55+ mph. By using an average speed of 45 mph across a route, Carrier A's drivers indicated they were less anxious about unrealistic delivery deadlines and the HOS regulations.

Technologies

Carrier A began pilot testing AEB systems in 2012. During this pilot test, Carrier A saw a positive ROI and quickly realized the need to implement across the entire fleet. Thus, Carrier A

began to order AEB systems on all new tractors, and by the end of 2018, AEB was implemented across 100% of Carrier A’s tractors. Additionally, starting in 2018, all of Carrier A’s trucks were also equipped with LDW, BSW, and video-based OSM systems. The implementation of these technologies resulted in a 56% reduction in preventable rear-end crashes.

Carrier A indicated drivers were skeptical when trucks were first equipped with AEB. They reported hesitance because they believed they would not be in control of the vehicle. However, after experiencing the AEB system prevent a crash, drivers quickly became advocates of the technology.

Top Recommendations

From Carrier A’s perspective, the training program and AEB provided the largest contribution to the significant safety improvement since 2012.

CARRIER B

Table 3 shows the period of time for Carrier B’s safety improvement, the safety outcomes that improved during the time period, and the magnitude of improvement.

Table 3. Carrier B Safety Improvement

Time Period for Safety Improvement	Safety Area Targeted	Objective Measure of Safety Improvement
2018	1. FMCSA-reportable crashes 2. CSA Crash Indicator BASIC 3. CSA Unsafe Driving BASIC	1. 31.7% reduction in FMCSA-reportable crash rate 2. 70 percentile improvement in CSA Crash Indicator BASIC 3. 49 percentile improvement in CSA Unsafe Driving BASIC

Carrier B has historically been a safe fleet. However, Carrier B’s crash statistics began to increase between 2013 and 2017. During this time period, Carrier B’s Vice President of Safety retired. A replacement Vice President of Safety was hired; however, this individual was not successfully maintaining the same safety culture within the fleet. As a result, the crash statistics and Carrier B’s CSA BASIC categories got worse, including a CSA Crash Indicator BASIC above the 90th percentile. In an effort to reverse this trend, Carrier B hired a new Vice President of Safety in February 2018. Following this hire, Carrier B experienced a 31.7% reduction in FMCSA-reportable crashes, a 70 percentile improvement in the CSA Crash Indicator BASIC score, and a 49 percentile improvement in the CSA Unsafe Driving BASIC score. The following subsections describe the specific programs Carrier B used to improve safety.

Driver Hiring

Between 2013 and 2017, Carrier B deviated from their historical driver hiring practices. This deviation occurred when the previous Vice President of Safety retired. After the Vice President of Safety retired, Carrier B frequently made exceptions to the driver hiring criteria in an effort to hire enough drivers to meet the demand. Starting in February 2018, Carrier B returned to the previously successful hiring policies and did not make any exceptions in hiring criteria. First,

Carrier B participated in FMCSA's PSP. Through the PSP and in combination with MVRs, Carrier B closely examined each applicant's previous driving history. During the initial review of applicants driving history, Carrier B prioritized the following:

- Zero preventable FMCSA-reportable crashes within the previous 3 years
- Zero serious moving violations as defined by FMCSA
- Zero substance abuse indications (i.e., failed drug tests) and convictions for driving under the influence
- A stable work history

Returning to these strict standards did present challenges for Carrier B. First, Carrier B's hiring costs rose, as it was more difficult to find drivers and complete a thorough background check. Second, as these criteria made it more difficult to find qualified drivers, the seated truck numbers dropped significantly, causing concern among other top management. However, after implementing the program for 8 months, the number of seated trucks returned to previous levels. Third, implementing the revised hiring criteria required significant coordination with driver recruiters. Fourth, some current drivers did not meet the stricter criteria. However, over time, Carrier B offered these drivers additional training, or in some cases, terminated their employment. Finally, Carrier B implemented hair drug testing in February 2018. Since that time, Carrier B hair testing has resulted in 10 times more positive tests compared to traditional urine testing. Carrier B indicated hair testing generated a positive ROI through a better selection of drivers.

Driver Training

Carrier B hired newly licensed commercial driver's license (CDL) drivers. To reduce the risk associated with newly licensed drivers, Carrier B paired new drivers with less than 6 months of experience with a driver trainer for the first month of employment. During this month, trainee and trainer did not operate as a team. Instead, the trainer was more of an in-cab instructor. The new driver was responsible for driving the first 11 hours each day. After the new driver logged 11 driving hours, the trainer took over and drove the final 3 hours. This provided the new driver with 3 additional hours of on-the-job training in the truck each day. During this time, the trainer demonstrated additional best practices for operating the truck.

In addition to pairing new drivers with a trainer for the first month, Carrier B implemented an enhanced road test to evaluate whether new drivers were ready to graduate from driving with a trainer. If a driver failed the enhanced road test, they were required to go back on the road with the trainer. Additionally, all drivers hired, regardless of previous experience, were required to complete the enhanced road test. The enhanced road test involved the following elements:

- Hooking up the trailer
- Conducting the pre-trip inspection
- Safely completing a 45-minute drive including three backing maneuvers, three right turns, and three left turns
- Unhooking the trailer

Finally, Carrier B equipped all trucks with a video-based OSM system and telematics device. Using data generated by the OSM device, all drivers received regular safety coaching. Similar to how professional athletes review footage from practices and games, drivers and driver coaches reviewed video footage to refine driving skills and identify areas for improvement.

Organizational Safety Culture and Management Programs

Carrier B's safety culture was driven from the top management and was introduced to drivers during the initial orientation. During orientation, all drivers heard from Carrier B's Chief Financial Officer, Vice President of Safety, Vice President of Operations, and Lead Driver Coach about prioritizing safety. Starting in February 2018, all employees received a safety pledge, which incorporated safety expectations from all departments in the organization. This included drivers, managers, dispatchers, maintenance personnel, and executives.

The core of Carrier B's safety culture was that driver safety always came first. Regarding driver fatigue, management instructed all dispatchers and drivers never to push exceptions to the HOS. If a driver ran out of hours, or was close to running out of hours without a planned location to stop, dispatch instructed the driver to pull off the road. Management terminated anyone in operations or dispatch who pushed a driver to drive beyond the HOS rules. Similarly, if a truck began to experience maintenance issues, management instructed drivers to immediately park until maintenance fixed the issue. There were zero exceptions made solely to get a load delivered on time.

Carrier B also implemented driver scorecards to encourage drivers to drive safely. Drivers who remained incident and violation free for 1 month earned up to an additional 4 cents per mile. To help drivers track their score, Carrier B developed a driver app. On the app, drivers could access their score and compare it to the overall driver average.

Finally, Carrier B reinforced its safety culture through its driver-coaching program. As mentioned above, all drivers received coaching based on the OSM and telematics data. Carrier B ensured all driver-coaching sessions were non-confrontational and positive. The purposes of these coaching sessions were not to punish drivers; instead, they were to help drivers improve. Management designed these coaching sessions to help drivers reduce unsafe behaviors over time with the expectation that changes in behavior are gradual. A full-time coach who has won national driver championships with multimillion crash free miles administered all coaching sessions. Additionally, upper management periodically joined coaching sessions to reinforce their commitment to safety and to offer support and gather feedback.

Technologies

In addition to OSM device and telematics device, Carrier B equipped its trucks with the best safety technologies available in efforts to prevent crashes. These additional technologies included LDW, ACC, AEB, and RSC on trailers. Carrier B indicated the implementation of these technologies contributed to the reduction in crashes.

Of the technologies used, Carrier B believed the OSM system had the largest safety impact. Additionally, Carrier B successfully used these data for driver exonerations. Despite these benefits, Carrier B did experience driver resistance. To help reduce this resistance, Carrier B

created a list of longtime drivers with an established history of safe driving. After all other trucks had been equipped, the safety personnel held a meeting with these drivers. During this meeting, drivers reviewed safety data from the entire fleet. Additionally, management offered these drivers the option to turn off the inward facing camera. After this meeting, all drivers agreed to use the OSM system. Currently, Carrier B is developing criteria for turning the inward facing camera back on.

Carrier B did have issues with the first generation of LDW systems. The previous generation of LDW systems produced a significant amount of false alerts. This caused drivers to become annoyed and contributed to drivers becoming habituated to the alerts. As a result, Carrier B unhooked all LDW systems. Unlike the previous generation of LDW, the generation subsequently equipped on the trucks was much better. Carrier B reported no longer experiencing an excessive amount of false alerts, and drivers no longer complained about the technology.

Vehicle Maintenance

Carrier B did not implement many new vehicle maintenance policies. The only change was to implement a new pre-trip inspection list. Carrier B used a specific pre-trip inspection list for flatbed trailers and another for reefer trailers. Additionally, the pre-trip inspection lists were specific to the types of loads hauled.

Top Recommendations

Carrier B’s top recommendation to other fleets looking to improve safety was to use a video-based OSM system paired with regular driver coaching. Carrier B also highly recommended the use of AEB and LDW to prevent crashes along with strict hiring criteria.

CARRIER C

Table 4 shows the period of time for Carrier C’s safety improvement, the safety outcomes that improved during the time period, and the magnitude of improvement.

Table 4. Carrier C Safety Improvement

Time Period for Safety Improvement	Safety Area Targeted	Objective Measure of Safety Improvement
2013–2018	<ol style="list-style-type: none"> 1. Preventable crashes 2. CSA Unsafe Driving BASIC 	<ol style="list-style-type: none"> 1. 75.6% reduction in preventable crashes 2. 17 percentile improvement in CSA Unsafe Driving BASIC

In 2011, Carrier C noticed a troubling trend of increasing crash rates. Although the crash rates and CSA scores did not reach the CSA threshold, they were well below Carrier C’s internal safety goals. In an effort to reverse the increased crash statistics and CSA scores, Carrier C hired a new Director of Safety, who conducted a major overhaul of many safety programs within the fleet. Using these strategies, Carrier C experienced a significant reduction in preventable crashes. Although exposure did not change between 2015 and 2018, Carrier C experienced a reduction from 78 preventable crashes in 2015 to 19 preventable crashes in 2018. This represents a 75.6%

reduction in preventable crashes. Additionally, Carrier C experienced a 17 percentile improvement in their CSA Unsafe Driving BASIC score from 2013 to 2018. The following subsections describe the specific programs Carrier C used to improve safety.

Driver Hiring

Before Carrier C hired the new Director of Safety in 2011, they had very lenient driver hiring policies. One of the first things the Director of Safety addressed was the hiring policy. As part of the new hiring policy, Carrier C implemented the following criteria:

- No more than two overall speeding violations in the previous 12 months
- No more than one speeding violation greater than 15 mph over the posted speed limit
- Zero preventable rear-end crashes or bridge strikes in the previous 12 months
- Zero preventable sideswipe, jackknife, rollover, or run-off-road crashes within the previous 24 months
- No more than four preventable crashes in the previous 3 years
- A minimum of 12 months driving experience after being involved in a preventable crash before being hired

At first, Carrier C did not offer any exceptions to these criteria. However, in the previous 2 years, Carrier C revised the policy so every MVR is subject to the Director of Safety's discretion. In other words, a driver may exceed one of the hiring criteria, and the Director of Safety could still approve the hire under specific circumstances.

Driver Training

In 2012, Carrier C implemented a driver finishing school. This enabled them to hire newly licensed CDL drivers and provide additional behind-the-wheel training. Each driver with less than 6 months driving experience was required to go through the finishing school. During the finishing school, drivers went on the road with a trainer for 30 days. During these 30 days, the student driver did the majority of the driving while the trainer provided feedback and tips. Often, this meant the student driver was responsible for the first 11 hours of driving and the trainer was responsible for the last 3 hours. During these 30 days, the finishing school coordinator monitored all training activity.

At the end of the 30 days, student drivers returned to Carrier C's home terminal for an in-class training component. During this in-class component, a retired safety director covered the Smith System for defensive driving, strategies for effective trip planning, the HOS requirements, a review of the ELD device, and paperwork requirements. Following the in-class portion of the finishing school, students were required to pass an extended road test to specifically test for defensive driving techniques and aggressive driving tendencies. If a driver did not pass the extended road test, Carrier C assigned a different trainer for 2 additional weeks of on-the-job training.

Carrier C also provided biannual safety meetings for all drivers at every terminal. Each safety meeting was an open forum where drivers discussed aggressive driving habits and reviewed strategies for remaining safe. Following each of these biannual safety meetings was a family

cookout. Carrier C used these family events to reinforce its family culture and discuss the importance of families in promoting safe behaviors. Specifically, Carrier C asked drivers' families to ensure drivers practiced good habits in their personal vehicles.

Organizational Safety Culture and Management Programs

The Director of Safety's primary role upon hire was to build a strong safety culture. One of the first tasks was to make sure the safety department was not the only department responsible for and discussing safety. This involved making sure all employees bought in to the safety culture. To do this, the Director of Safety's first meeting was with the driver managers. As these managers were the ones with daily communications with drivers, it was critical that they were onboard with all programs to improve safety. The Director of Safety held group meetings with these driver managers where everyone engaged in team building activities. The purpose of these activities was to encourage managers to communicate with unfamiliar individuals. The Director of Safety then shared Carrier C's overall data on crash rates and CSA scores. Many of these managers had never seen the overall crash statistics for the fleet. By sharing these data, the Director of Safety successfully generated buy-in with the front line managers.

Following these group meetings, the Director of Safety held one-on-one meetings with each driver manager. During these meetings, each driver manager viewed an analytical breakdown comparing their drivers' safety data to other drivers within the fleet. The Director of Safety and each of the driver managers collaboratively developed strategies to improve safety and discussed how to improve the safety culture.

Other strategies to build a strong safety culture included frequent safety communications. Each driver manager was required to send out a dedicated message to their drivers two times a week with a focus on safety topics. These communications reinforced the importance of safety and reminded drivers of safe driving practices. Additionally, each message from the driver managers ended in a reminder to drive safely.

As mentioned above, Carrier C created a family environment despite its large size. To encourage a family environment, Carrier C invited drivers' family members to attend special events. As mentioned above, families were encouraged to take an active role in keeping drivers safe. During all family events, top management discussed the importance of doing everything possible to make sure drivers returned home to their families.

Carrier C also used a number of other management strategies designed to increase safety. First, the Director of Safety conducted quarterly meetings with the owner of the fleet. During these meetings, the Director of Safety presented the number of crashes and incidents within the quarter, the number of preventable versus non-preventable crashes, statistics on the most common types of crashes, the tenure of drivers involved in crashes, and location of crashes. Second, Carrier C used a safety bonus program to encourage safe driving. The safety bonus program rewarded drivers without a preventable crash each month.

Dispatching and Scheduling

In 2013, Carrier C reduced the number of drivers under each driver manager. Prior to 2013, driver managers were responsible for 40 to 50 drivers. Beginning in 2013, driver managers were

responsible for 35 to 40 drivers. This allowed each driver manager additional time to focus on individual drivers.

Technologies

Carrier C implemented a number of safety technologies across its fleet. First, in 2012, Carrier C equipped all trucks with a telematics device designed to track speeding. With the telematics program, Carrier C reduced its CSA Unsafe Driving BASIC score below the alert threshold for the first time since the CSA program began in 2010. Additionally, in 2015, Carrier C began purchasing trucks with AEB systems. At the time of the case study, 75% of the fleet was equipped with AEB. Finally, Carrier C started to equip all trucks with an outward-facing video-based OSM system.

Vehicle Maintenance

Carrier C did not revise vehicle maintenance programs as part of the increased attention to safety.

Top Recommendations

Carrier C’s top recommendation to other fleets struggling to improve safety was to focus on safety culture. Changing safety culture was not easy and took a long time. Carrier C cautioned that results are not immediate; however, safety improvements build upon the success of previous years.

CARRIER D

Table 5 shows the period of time for Carrier D’s safety improvement, the safety outcomes that improved during the time period, and the magnitude of improvement.

Table 5. Carrier D Safety Improvement

Time Period for Safety Improvement	Safety Area Targeted	Objective Measure of Safety Improvement
2012–2018	<ol style="list-style-type: none"> 1. CSA Unsafe Driving BASIC 2. CSA Maintenance BASIC 3. CSA HOS BASIC 4. Preventable, FMCSA-reportable crashes related to AEB and RSC 	<ol style="list-style-type: none"> 1. 45 percentile improvement in CSA Unsafe Driving BASIC 2. 24 percentile improvement in CSA Maintenance BASIC 3. 70 percentile improvement in CSA HOS BASIC 4. Eliminated all preventable rear-end crashes and rollovers

In 2012, Carrier E experienced a high level of HOS violations that resulted in CSA scores above the 90th percentile. To address this issue, Carrier E’s owner hired a new Director of Safety. The new Director of Safety’s first initiative was to implement ELDs in all trucks. In addition to ELDs, the Director of Safety implemented a number of other safety improvement initiatives. As a result of adopting ELDs and all the other safety improvement initiatives described below, Carrier E experienced the following safety improvements:

- A 45 percentile improvement in the CSA Unsafe Driving BASIC
- A 24 percentile improvement in the CSA Maintenance BASIC
- A 70 percentile reduction in the CSA HOS BASIC
- A reduction in the number of preventable rear-ends and rollovers from an average of three and two per year, respectively, to zero for the previous 3 years

The following subsections describe the specific programs Carrier D used to improve safety.

Driver Hiring

The new Director of Safety did not substantially change Carrier D's hiring policies. Carrier D participated in FMCSA's PSP program and reviewed applicants' MVRs. Carrier D's hiring criteria included the following:

- A minimum of 1 year driving experience
- At least 23 years old
- No more than three moving violations in the previous 3 years
- No more than two moving violations in the previous 12 months

If an applicant fell short on one of the four criteria (except the age requirement), the Director of Safety was still able to hire the driver, but required supplemental training (e.g., additional pre- or post-trip inspection training, safe driving training, etc.) or lowered the speed limiter setting.

Driver Training

All new hires were required to complete in-person safety training. This training began with the Director of Safety sharing Carrier D's overall safety outlook with the drivers. This allowed drivers to know the entire fleet's safety scores and crash numbers. The purpose of sharing this information was to help drivers understand why Carrier D developed specific safety programs. It also reinforced how each individual driver's behavior influenced the entire fleet's scores. Other information included in the mandatory initial training centers around the importance of safety issues, such as following distance, speed, and defensive driving.

Carrier D also offered monthly retraining and refresher information to all drivers. Usually this training consisted of the Director of Safety sending several pages of information electronically to all drivers along with a short quiz. This monthly retraining/refresher information often targeted seasonal impacts on trucking.

Finally, each driver underwent an annual safety review. The purpose of this annual review was to identify drivers who excelled over the past year or to identify areas where drivers might need additional training.

Organizational Safety Culture and Management Practices

The Director of Safety immediately worked with the carrier's owners to generate buy-in among top management. This included involving the operations department in supplementary training on HOS regulations. Additionally, the Director of Safety conducted weekly meetings with the

operations department to review the previous week's data related to safety, violations, and HOS. The Director of Safety also implemented a communication plan where all operations management received an immediate alert when a driver failed an inspection. By gaining buy-in from operations, Carrier D began to change the cultural importance of the HOS.

In 2014, the Director of Safety changed the operational software used to schedule drivers in a further attempt to address the high CSA HOS BASIC. The new software allowed dispatch to see drivers' hours in real-time. This enabled dispatch, operations, and safety to monitor real-time progress to reroute drivers or reschedule delivery appointments if needed without having to push drivers to the limits of the HOS regulations.

A third change the Director of Safety implemented to address the HOS violations was educating everyone in the organization on the importance of HOS regulations. Changing the safety culture required safety to be everyone's job, not just the safety department's. This involved educating all departments, face-to-face communication with drivers, managers, and dispatch, and walking dispatch through the use of the ELD. The importance of the HOS and how the HOS go beyond driving time were constantly reiterated; HOS include regulations for loading, unloading, waiting, and rest.

The Director of Safety also implemented a number of other management programs to increase safety and improve the safety culture. These included a safety/performance bonus, driver of the year program, discipline policy tied to the safety bonus, and an increased attention to driver wellness. Carrier D's safety/performance bonus program occurred quarterly. To reach the \$0.02 per mile safety bonus, drivers must have had zero moving violations, zero bad inspections, zero preventable crashes, and zero out of service violations. The annual safety bonus equaled \$0.01 cent per mile if the driver earned all four quarterly bonus. Further, the Driver of the Year winner must have earned eight quarterly safety bonuses in a row to be eligible to spec and drive a brand new truck. Paired with the safety bonus was a progressive discipline policy. This policy included lowering speed limiter settings if drivers received moving violations, and mandatory suspensions and possible termination for receiving reckless driving violations.

Finally, the Director of Safety implemented a policy where someone always answered the phone, 24 hours a day, 7 days a week. This ensured someone was always available to help a driver without calls going to a voicemail. Additionally, the Director of Safety trained dispatchers to listen for key words indicating an increase in driver distress. If a dispatcher noticed a driver feeling distressed, the dispatcher immediately alerted the Director of Safety for a follow-up conversation. The Director of Safety reached out to the driver to complete a wellness check to identify ways to ease the distress (e.g., offer a pay advance, provide a few extra days at home, assign a relief driver, etc.).

Dispatching and Scheduling

Carrier D implemented ELDs fleet wide in 2012. Using ELDs and the new operational software allowed dispatch and other managers to schedule drivers realistically within the HOS regulations.

Technologies

In 2015, Carrier D began to purchase trucks equipped with a suite of collision mitigation technologies. This suite of technologies included AEB, LDW, and RSC. At the time of the case study, 50% of the fleet was equipped. Since implementing these technologies, Carrier D had not experienced a single rear-end crash or rollover. Prior to 2015, Carrier D averaged three rear-end crashes and two rollover crashes a year. As part of the safety suite, Carrier D used a video-based OSM system. The Director of Safety reviewed all video events and used the videos and data for one-on-one driver coaching sessions.

Additionally, Carrier D used a separate telematics device in an effort to prevent speeding. However, the telematics system became obsolete when the trucks were equipped with the collision mitigation suite. Finally, Carrier D's trucks were equipped with speed limiters set at 65 mph, though a drivers' performance could result in raised or lowered governed speed.

Vehicle Maintenance

The Director of Safety saw the need to invest in new equipment as part of the safety program overhaul. The fleet moved to a 3-year replacement cycle. Additionally, mechanics visually inspected each truck each time it returned to the terminal. Previously, Carrier D only repaired trucks when something was broken. Rather than waiting for parts to break down, Carrier D implemented a new policy to replace parts before they broke. Finally, Carrier D switched to air-disc brakes, which helped improve maintenance. These vehicle maintenance improvements resulted in Carrier D's lowest vehicle maintenance score.

Top Recommendations

According to Carrier D, a well-rounded, strong safety culture was the best way to improve safety. In developing a strong safety culture, the adoption of collision mitigation technologies and investing in new equipment was critical in reducing crashes.

CARRIER E

Table 6 shows the period of time for Carrier E's safety improvement, the safety outcomes that improved during the time period, and the magnitude of improvement.

Table 6. Carrier E Safety Improvement

Time Period for Safety Improvement	Safety Area Targeted	Objective Measure of Safety Improvement
2012–2018	1. FMCSA-reportable crashes	1. 35.8% reduction in FMCSA-reportable crashes (10% reduction in 2018 alone)

Carrier E had a long history of being a safety conscious company and regularly conducted internal and external benchmarking to determine areas for safety improvements. By maintaining a strong safety culture and implementing several new safety initiatives (described below), Carrier E experienced a gradual decline in FMCSA-reportable crashes over the past 6 years. Between

2005 and 2011, Carrier E averaged 9.5 FMCSA-reportable crashes per year. Between 2012 and 2018, Carrier E averaged 6.1 FMCSA-reportable crashes per year, representing a 35.8% reduction in FMCSA-reportable crashes. Furthermore, 10% of this reduction came in the 8 months prior to the case study.

The following subsections describe the specific programs used by Carrier E to maintain a strong safety culture and prevent crashes.

Driver Hiring

Within the 8 months prior to the case study, Carrier E used a personality assessment during the hiring process. This assessment focuses on matching applicant personality to “job behaviors.” This new tool resulted in some improvements in the selection of safe drivers.

Carrier E’s hiring criteria were not changed, as they aligned well to its strong safety culture. Carrier E’s hiring criteria included the following:

- Minimum of 23 years old
- Must hold a CDL
- No more than three moving violations in the previous 3 years
- No major violations in the previous 3 years
- No preventable FMCSA-reportable crashes in the previous 12 months
- No convictions for driving under the influence in the previous 5 years and no more than one ever
- No more than three jobs in the past 12 months

In addition to these strict hiring criteria, each applicant was required to pass a DOT physical using Carrier E’s in-house physician. As part of this physical, the physician screened each driver for obstructive sleep apnea. If warranted, the physician sent drivers for a sleep study paid for by Carrier E. In addition to the DOT physical, each applicant went through a physical capacity test. This physical capacity test included testing on an isokinetic machine to measure strength limits. Finally, Carrier E required all applicants submit to a hair drug screen. Carrier E had a 90-day detection window for positive drug tests. Carrier E reported excellent results from using the hair test.

Driver Training

Although Carrier E did not offer a CDL school, it hired newly licensed drivers with an agreement to complete its finishing school. All newly hired drivers with 6 months of experience or less were required to complete the finishing school. This finishing school paired inexperienced drivers with an experienced driver for behind-the-wheel training until the new driver was ready to drive solo.

During the orientation program, Carrier E provided a comprehensive overview of its safety program to all new drivers. This included a half-day review of best practices for maintenance. The second day included information on how to operate the trucks, an overview of the technologies installed on the trucks, a review of safety policies, and an introduction to top

management. Finally, a full day was devoted to a road test and a driving simulator skills test (implemented at the end of 2017).

In addition to this initial driver training and introduction, Carrier E used its driving simulator for quarterly refresher training and remedial training after a crash or near crash. With the driving simulator, Carrier E recreated crashes or near crashes for drivers to practice skills to prevent these events from occurring in the future.

Organizational Safety Culture and Management Practices

During orientation, Carrier E demonstrated top management support for safety by showing a video from the owner discussing his commitment to safety. In this video, the owner instructed drivers to immediately pull over if they ever had a problem while driving, were out of hours, felt tired, etc. Carrier E would reschedule the load with no questions asked. The owner stressed nothing was more important than the safety of the drivers.

Additionally, Carrier E demonstrated top management support for safety by its investment in the latest advanced safety technologies, health and wellness programs, and driver scorecards. Carrier E created a full sleep apnea program for diagnosed drivers. Carrier E paid for all sleep studies and the continuous positive airway pressure machine for any driver (if needed). If Carrier E paid for the machine, it asked all drivers to make a 1-year commitment to stay with the company. After 1 year, the driver kept the machine even if they left the fleet.

Carrier E's scorecard was based on inspection-related data and involvement in crashes. Drivers earned points for longevity, miles without incident, and clean inspections. These points combined for the possibility to earn upwards of \$3,000 a year.

Dispatching and Scheduling

Dispatchers followed through with Carrier E's policy to reschedule all loads if the driver felt unsafe or if drivers exceed allowable driving/on-duty hours.

Technologies

Carrier E's ownership invested heavily in advanced safety technologies. Carrier E's trucks were equipped with a video-based OSM system, speed limiters, AEB, and ACC. The video-based OSM program equipped on Carrier E's trucks only included forward facing cameras. Inward facing cameras were seldom used; however, if a driver was involved in several crashes, Carrier E turned on the inward facing camera to identify any behaviors in need of correction.

Although the video-based OSM program resulted in significant safety improvement within drivers, there was not a large overall reduction in events. This was because of a high driver turnover rate. New drivers were often responsible for many risky events and experienced drivers typically had very few events.

Carrier E began purchasing a collision mitigation system in January 2016. This technology integrated with the video-based OSM device to record all collision mitigation alerts and activations. Starting in 2019, all new trucks were equipped with the latest generation of the

collision mitigation system. Carrier E experienced initial driver resistance to the collision mitigation system; however, resistance faded once a driver experienced the technology prevent a crash.

Vehicle Maintenance

Carrier E recently implemented a new vehicle inspection protocol. One technician was dedicated to conducting a systems check on all vehicles as they returned to the terminal. This included checking the dash lights for indications of air leaks, anti-lock braking system codes, and other warning lights. Additionally, this technician completed a full trailer inspection every time a trailer returned to the terminal. Other maintenance personnel were responsible for inspecting brakes and tires.

Top Recommendation

Carrier E reported leadership had the largest impact on a fleet’s safety culture. A large part of this was a demonstrated commitment to safety and a willingness to invest in safety equipment. Specifically, Carrier E recommended that a strong safety culture should include collision mitigation technology and a video-based OSM system.

CARRIER F

Table 7 shows the period of time for Carrier F’s safety improvement, the safety outcomes that improved during the time period, and the magnitude of improvement.

Table 7. Carrier F Safety Improvement

Time Period for Safety Improvement	Safety Area Targeted	Objective Measure of Safety Improvement
2017–2018	<ol style="list-style-type: none"> 1. FMCSA-reportable crash rate 2. CSA Crash Indicator BASIC 	<ol style="list-style-type: none"> 1. 66.3% reduction in FMCSA-reportable crash rate 2. 44 percentile improvement in CSA Crash Indicator BASIC

Historically, Carrier F had a strong safety culture with a good safety record. As part of its strong safety culture, Carrier F regularly conducted internal and external benchmarking in an effort to identify areas for improvement. Between 2013 and 2017, Carrier F averaged 0.86 FMCSA-reportable crashes per million miles. In 2018, Carrier F experienced a 66.3% decrease to 0.29 FMCSA-reportable crashes per million miles. Despite already having a low crash rate, Carrier F was able to become even safer. The following subsections describe the policies and programs Carrier F used to maintain a low crash rate and the policies and programs Carrier F used to further reduce crashes.

Driver Hiring

As Carrier F primarily hauls oversized loads, it implemented strict hiring criteria. These criteria included the following:

- Minimum of 23 years old
- At least 3 years of driving experience in the previous 5 years
- Zero crashes in the previous 5 years
- Zero citations in the previous 12 months

Due to these strict hiring criteria, Carrier F had difficulties finding qualified drivers. Thus, Carrier F focused on retaining existing drivers. Carrier F's driver retention efforts began with pay. Carrier F paid its drivers by the hour instead of by the mile. Carrier F found this reduced driver stress related to traffic delays or detention time. Additionally, Carrier F provided drivers a \$1 per hour raise during each of the previous 3 years. Finally, Carrier F offered a \$500 retention bonus if a driver stayed with the fleet for 60 days after hire.

Carrier F also implemented a referral program. Drivers who referred an applicant who was hired received a \$100 bonus. If the referred driver stayed with Carrier F past 60 days, the driver who made the referral earned an additional \$900.

Driving Training

Each driver had a one-on-one meeting with the Safety Supervisor to review company safety policies and demonstrate how to operate the ELD. The Safety Supervisor personally introduced all new hires to all administrative personnel, including dispatchers, maintenance personnel, front desk personnel, management, and the owner. Following this meeting and introduction, the new hire did a ride-along with an experienced driver. For the remainder of the first 2 weeks, all new hires shadowed the trainer for at least 2 weeks while the drivers became comfortable operating the truck and safely delivering the oversized loads.

All drivers received training each quarter, which focused on seasonal issues and topics, defensive driving strategies, new regulations or guidance from FMCSA, or other topics related to geographic interest (i.e., permits for the spotted lanternfly). Finally, the Safety Supervisor regularly sent memos or notes via the dispatching devices with reminders and/or tips for safe driving.

The Safety Supervisor also implemented a process for peer-observation and safety reporting. As part of this program, the Safety Supervisor encouraged drivers to provide feedback on topics and skills in need of trainings. To encourage drivers to report safety issues, the Safety Supervisor implemented an open door policy. Drivers were encouraged to provide safety-related information via text, call, face-to-face meetings, a suggestion box, and/or through email.

Organizational Safety Culture and Management Practices

Carrier F's safety culture was built around a strong family environment. This included everyone knowing each other's name. Additionally, the Safety Supervisor developed a good repertoire with drivers. The drivers were willing to report unsafe conditions or risky behaviors to the Safety Supervisor. Because the Safety Supervisor actively listened to feedback and treated drivers like members of the family, drivers understood that the Safety Supervisor wanted to keep everyone safe.

The family culture also allowed drivers to feel more relaxed while driving. The drivers were not worried someone was looking over their shoulder to get them in trouble. Instead, they always knew someone in the fleet was there to help if needed. The Safety Supervisor made a concerted effort to actively listen to drivers' feedback and immediately follow through on driver requests or questions. This helped drivers know their concerns were important and encouraged drivers to participate in the safety program.

The Safety Supervisor also scheduled regular ride-alongs with drivers. This helped the Safety Supervisor understand the difficulties that drivers face on a daily basis and got drivers to buy-in to the safety program. Additionally, the Safety Supervisor visited delivery sites to demonstrate availability and commitment to helping drivers if needed. Carrier F also used a safety bonus program. Each year, drivers had the potential to earn a 2% bonus in each month without an incident.

Dispatching and Scheduling

Carrier F implemented ELDs in 2017 with the ELD mandate. Carrier F only employed two dispatchers, so each dispatcher knew each driver and their preferences. Carrier E strictly enforced the HOS regulations. If a driver ran out of hours, dispatch instructed drivers to pull over and immediately sent a replacement driver to pick them up.

Technologies

Carrier F began to equip all trucks with a forward facing video-based OSM system in 2017. As part of this program, the Safety Supervisor reviewed all the videos and brought drivers in for individual coaching sessions to review events. The focus of these coaching sessions was a discussion to figure out what happened and how to prevent it from occurring again. The Safety Supervisor made an effort to be positive during the coaching session. In addition to the video-based OSMs, all newly purchased trucks have been equipped with AEB and LDW since 2018.

Vehicle Maintenance

Carrier F had its own shop with maintenance personnel. The maintenance shop operated 24 hours a day to fix issues quickly. If a driver noted an issue with a truck/trailer, the maintenance department immediately brought it into the shop. Carrier F also regularly serviced all trucks and trailers. The maintenance department serviced each truck every 7,500 to 10,000 miles, and serviced trailer brakes and tires every 30 days.

Top Recommendations

Creating a family environment was Carrier F's top recommendation for carriers looking to build a strong safety culture. The family culture created an environment where drivers and management helped each other, which in turn, helped decrease drivers' anxiety and stress. Carrier F's second recommendation was the use of strict hiring criteria. Once a safe driver was hired, the family culture helped to retain them.

CARRIER G

Table 8 shows the period of time for Carrier G’s safety improvement, the safety outcomes that improved during the time period, and the magnitude of improvement.

Table 8. Carrier G Safety Improvement

Time Period for Safety Improvement	Safety Area Targeted	Objective Measure of Safety Improvement
2012–2018	<ol style="list-style-type: none">1. FMCSA-reportable crashes2. CSA Crash Indicator BASIC	<ol style="list-style-type: none">1. 26.3% reduction in FMCSA-reportable crashes since 20122. 66.3% reduction in FMCSA-reportable crash rate from 2017 to 20183. 38 percentile improvement in CSA Crash Indicator BASIC since 2016

In 2012, Carrier G came under new ownership. Although the safety record of the previous ownership was not poor, Carrier G’s new ownership realized there were opportunities for improvement. Carrier G’s new ownership wanted to start with all new equipment. Thus, in 2012, Carrier G replaced the entire fleet of trucks and began using ELDs. Additionally, in October 2017, Carrier G implemented all trucks with a video-based OSM system. As a result of these safety improvements, Carrier G experienced a 26.3% reduction in FMCSA-reportable crashes despite doubling in size. Additionally, since 2017, Carrier G’s crash rate was reduced from 1.04 FMCSA-reportable crashes per million miles to 0.35 FMCSA-reportable crashes per million miles. Finally, Carrier G’s CSA Crash Indicator BASIC score has improved 38 percentile points since 2016. The following subsections provide detailed information on the safety programs Carrier G has used to achieve these results.

Driver Hiring

Carrier G hired experienced drivers, with a preference for drivers with live haul experience. Carrier G participated in FMCSA’s PSP. Carrier G only had three strict hiring criteria, which included the following:

- A minimum of 2 years driving experience
- A maximum of 5.5 MVR points
- Zero reckless driving violations

The Safety Director had final discretion on driving history. The Safety Director reviewed each applicants’ driving history to identify any trends for negative inspections. Additionally, each applicant’s crash history was under the discretion of the Safety Director, who called previous employers to seek recommendations. In addition to the hiring criteria, Carrier G asked all applicants to complete a fitness test at a local physical therapist during the pre-employment screening process. This agility test flagged mobility issues in an effort to identify accommodations and to match abilities to working conditions.

Driver Training

Carrier G had several driver training programs designed to improve safety. All new drivers went through a 3-day orientation to review carrier-specific policies, programs, and safety regulations. All new drivers without previous live haul experience were required to complete live haul training. The live haul training allowed new drivers to become comfortable with the live haul process. During the first week, new drivers rode along with an experienced trainer in the jump seat while completing all the required paper work. During the second week, the new drivers began to drive outbound (i.e., flatbed with empty coops) while the trainer rode in the jump seat. After another week or two, the new hire began driving the entire trip with the trainer in the jump seat. Solo routes began when the trainer indicated the new driver was ready. However, a trainer often shadowed the new driver to job sites to ensure the new driver was comfortable with the working conditions and/or route.

In addition to the intensive new driving training program, all drivers took part in regular training. The Safety Director held group-wide safety meetings focusing on seasonal topics. Additionally, Carrier G used computer-based training for all drivers. Each driver completed two to three online modules each month, focusing on seasonal or other relevant topics. These modules provided refresher training and reminded drivers of strategies and techniques related to safety.

Organizational Safety Culture and Management Practices

Carrier G attempted to build a close-knit community within the organization. This included inviting all employees and their families to company-sponsored holiday events. As the company was relatively small, all employees knew each other. This contributed to a family environment where all drivers, dispatchers, and managers supported each other and lent a hand to help anyone in need.

Dispatching and Scheduling

Carrier G implemented ELDs in 2012. The ELDs helped dispatchers plan routes more efficiently and allowed for better prediction of drivers' HOS. The ELDs also allowed Carrier G and the customers to know exactly where the cargo was at any time.

Technologies

As mentioned above, Carrier G equipped all their trucks with a video-based OSM system in October 2017. The Safety Director reviewed all video events and completed one-on-one counseling sessions with drivers. During these sessions, the objective was to work with the driver to identify ways to prevent near-crashes and crashes. The entire session was collaborative and not focused on finding blame. Additionally, in December 2017, a light vehicle crashed into one of Carrier G's trucks during a snowstorm. The driver of the light vehicle filed a suit implicating the truck driver as the cause of the crash. However, the video from the OSM device showed that the driver at Carrier G did nothing unsafe and the lawsuit was dismissed. This example of driver exoneration resulted in 100% driver buy-in of the program.

Starting in 2018, Carrier G started purchasing trucks equipped with AEB. The introduction of AEB increased drivers' following distances, and as a result, zero rear-end near-crashes have been recorded at Carrier G since implementation. Finally, Carrier G set its speed limiters to 68 mph.

Vehicle Maintenance

Carrier G made no significant changes to its vehicle maintenance program. Carrier G monitored CSA scores and DOT inspections. Carrier G had their own maintenance shop and personnel replaced components if a driver identified an issue, even if the parts were within DOT regulations.

Top Recommendations

Carrier G's top recommendation was to implement safety technologies. First, the video-based OSM system provided valuable data to reduce risky driving. AEB technologies proactively prevented crashes, and ELDs provided carriers with HOS data to assist in scheduling loads.

CARRIER H

Table 9 shows the period of time for Carrier H's safety improvement, the safety outcomes that improved during the time period, and the magnitude of improvement.

Table 9. Carrier H Safety Improvement

Time Period for Safety Improvement	Safety Area Targeted	Objective Measure of Safety Improvement
2014–2018	<ol style="list-style-type: none"> 1. FMCSA-reportable crashes 2. CSA Crash Indicator BASIC 	<ol style="list-style-type: none"> 1. 24.4% reduction in FMCSA-reportable crash rate 2. 39.7 percentile improvement in CSA Crash Indicator BASIC since 2014

Carrier H saw an upward trend in crashes that resulted in a CSA Crash Indicator BASIC percentile of 92.7. Carrier H hired a new Director of Safety to address the rising crash rate. By using the strategies below, Carrier H reduced its FMCSA-reportable crashes from 0.78 crashes per million miles in 2013 to 0.59 crashes per million miles in 2018. Additionally, Carrier H improved its CSA Crash Indicator BASIC score from the 92.7th percentile in 2014 to the 53rd percentile in 2018. The following subsections describe the safety programs Carrier H found successful in improving safety.

Driver Hiring

Carrier H participated in FMCSA's PSP. This program was the main source of information for making hiring decisions. Carrier H's hiring guidelines are listed below:

- Prefer a minimum of 1 year driving experience
- Zero preventable crashes

- No more than five points on the MVR over the past 5 years (two points are assigned to a major traffic citation and one point is assigned to a minor traffic citation)
- Positive referrals from previous employers

Based on these hiring guidelines, the Director of Safety conducted an in-person interview with each selected driver. This allowed the Director of Safety to get to know the driver prior to hire. The in-person interview also allowed the Director of Safety to match job responsibilities and routes with the drivers' expectations for home time, route lengths, etc. Carrier H found this significantly increased driver retention.

Driver Training

Upon hire, all new drivers went through a daylong on-the-job training. During this training, each new driver worked with an experienced, safe driver. The experienced driver showed the new driver how to operate the ELD, protocols for interacting with dispatch, and introduced the new drivers to all administrative, maintenance, dispatch, and management personnel.

Although Carrier H preferred to hire drivers with 1 year of experience, Carrier H hired new entrants if they performed well on the road test, had a clean MVR, and provided good referrals. If hired, all new entrants worked with an experienced driver. The experienced drivers worked with the new driver for several weeks until the new driver was ready to drive solo routes. During this time, the experienced driver provided feedback and suggestions to everyday situations.

All drivers participated in quarterly trainings conducted by the Director of Safety. Each quarter, all drivers attended a driver safety meeting at the main terminal. During this meeting, the Director of Safety had an open dialogue on the previous quarter's safety data. The Director of Safety shared all the safety and violation data with the drivers, including the total costs of crashes. These quarterly safety meetings often included additional guest speakers from outside agencies to discuss timely or relevant information. Finally, each quarterly safety meeting included an open discussion about specific situations or maneuvers drivers struggle to perform correctly.

The last component of Carrier H's training program was the use of online training modules. These modules were 3–5 minutes long and incorporated videos, information, and quizzes. The Director of Safety assigned drivers several of these videos each month based on common crash types or suggestions from drivers.

Organizational Safety Culture and Management Practices

The safety culture of Carrier H relied on honest, open communication between all drivers and the Director of Safety. Carrier H made a concentrated effort to schedule drivers based on their preferences, and the Director of Safety worked with dispatch in the event schedules did not match driver expectations. In an effort to develop driver accountability, drivers earned a yearly profit share bonus. When the carrier did well, Carrier H returned a portion of that profit to the drivers. This increased drivers' ownership in their work as well as their pride in safety.

Dispatching and Scheduling

To meet driver expectations and in efforts to improve safety, Carrier H focused on getting drivers home as much as possible, often every few days. This also led to Carrier H opening a new terminal to increase regional routes. The Director of Safety also provided HOS training to dispatchers. This helped dispatchers avoid making unrealistic schedules based on driving and on-duty hours. Further, dispatchers completed the same online monthly training as the drivers. This helped dispatch have a better understanding of what drivers go through while on the road.

Technologies

At the time of the case study, Carrier H did not have any advanced safety technologies. However, the safety department was evaluating video-based OSM systems. The Director of Safety found it difficult to generate buy-in from top management due to the large upfront costs. Additionally, Carrier H's management saw the improved crash data and was hesitant to implement additional strategies.

Vehicles Maintenance

Carrier H did not revise its vehicle maintenance program. It owned its own shop and the head of the maintenance department previously built trucks for a major truck OEM.

Top Recommendations

Carrier H's top recommendation for other fleets was to be careful about hiring criteria. Often drivers came to the company with driving experience. However, many of these drivers developed bad habits over time or received poor training. It was important to conduct a detailed road test in an effort to weed out these drivers. Secondly, Carrier H recommended working with the drivers to ensure there was open communication about all issues. This helped improve driver satisfaction and retention.

CARRIER I

Table 10 shows the period of time for Carrier I's safety improvement, the safety outcomes that improved during the time period, and the magnitude of improvement.

Table 10. Carrier I Safety Improvement

Time Period for Safety Improvement	Safety Area Targeted	Objective Measure of Safety Improvement
2017–2018	<ol style="list-style-type: none">1. All incidents2. FMCSA-reportable crashes3. CSA HOS BASIC	<ol style="list-style-type: none">1. 53.6% reduction in all incidents2. Zero FMCSA-reportable crashes3. 46 percentile improvement in CSA HOS BASIC score

Carrier I was a small family-owned fleet that had not been involved in many FMCSA-reportable crashes. However, it experienced an increase in less-severe incidents each year. Additionally, Carrier I's drivers always pushed the HOS limits with paper log books. In late 2016, Carrier I

hired a new Safety Manager to implement ELDs and reduce the number of carrier incidents. The Safety Manager equipped all trucks with ELDs during 2017. Additionally, starting in 2018, all trucks were equipped with a video-based OSM system. Along with the strategies below and the implementation of ELDs and video-based OSM system, Carrier I was able to reduce their incidents from 28 in 2017 to 13 in 2018, which represents a 53.6% decrease. Carrier I accomplished this reduction by eliminating most preventable incidents. Additionally, Carrier I averaged almost two FMCSA-reportable crashes per million miles prior to 2018. In 2018, Carrier I did not have any FMCSA-reportable crashes. Finally, Carrier I improved its CSA HOS BASIC score by 46 percentile points after implementing ELDs. The subsections below detail the policies and programs Carrier I uses to maintain a low crash rate.

Driver Hiring

Carrier I had a difficult time finding and retaining safe drivers. Thus, Carrier I only had one strict hiring criteria: drivers must have 3 years of experience. Beyond this requirement, all hires were subject to the Safety Manager's discretion. Carrier I did driver recruiting through word of mouth and offered a recruitment/referral program to current drivers. If Carrier I hired a referred driver, and that driver stayed 6 months, the referring driver received \$100.

Driver Training

Carrier I had three driver training programs. First, all new hires went through an initial safety training with the Safety Manager. This training involved reviewing the HOS requirements, an overview of all safety expectations, and a review of the carrier's safety programs and technologies. For the first several weeks after hire, each new driver worked with a senior driver for mentoring. Although the senior driver did not ride along with the new hire, the senior driver was available to provide feedback, answer questions, and help the new driver with any issues they may have encountered.

Second, Carrier I held biannual safety meetings. During these meetings, the Safety Manager reviewed the previous 6 months of crash and incident data. The Safety Manager also reviewed videos collected from the OSM system. The Safety Manager held an open discussion with the drivers to gather feedback on strategies to prevent similar situations in the future. Additionally, the Safety Manager discussed other high profile, real-life scenarios that occurred in the trucking industry within the previous 6 months. During these meetings, Carrier I invited external speakers to discuss additional topics of interests.

The third training program involved face-to-face coaching. The Safety Manager brought all drivers in for face-to-face meetings after every incident and/or periodically to review risky driving captured by the video-based OSM system. The focus of these meetings was to pinpoint what happened and how it could be prevented. The Safety Manager and drivers reviewed the video(s) and the drivers offered their opinions. Together, the Safety Manager and drivers developed an action plan to be used going forward.

Organizational Safety Culture and Management Programs

Carrier I had a family environment where all the drivers offered to help each other. Everyone within the fleet knew each other and drivers understood that management supported them. For

example, if a driver was unable to deliver a load because they were tired or ran out of hours, management and/or other drivers offered to complete the delivery. Additionally, if a driver had an issue, no matter the time of day, the Safety Director offered as much assistance as possible.

Dispatching and Scheduling

The main tool Carrier I used to attract and retain safe drivers was scheduling weekly home time. If desired, drivers started routes from their houses. Carrier I found this approach met driver expectations and eased the pressure and stress felt when leaving their family for extended periods of time. Additionally, as the fleet is small, dispatchers knew each individual's preferences. Dispatchers used this knowledge and the data from the ELD to schedule routes to align with drivers' sleep schedules.

Technologies

As previously mentioned, Carrier I equipped all trucks with a video-based OSM system in early 2018. Initially, there was a lot of push back from drivers regarding the technology. To help increase buy-in, the Safety Manager had a representative from the insurance agency make a presentation on the benefits of video-based OSM systems. Additionally, the Safety Manager held in-depth discussions with drivers about the decision making process behind implementing the OSM systems. Finally, the Safety Manager made sure to address questions and concerns about privacy. Carrier I governed trucks at 70 mph.

Vehicle Maintenance

Carrier I did not implement any changes to its vehicle maintenance practices.

Top Recommendations

Carrier I's recommendation to other fleets was to build a safety culture where drivers understand that management values safety. Carrier I's second recommendation was to equip trucks with video-based OSM systems and use the data generated by ELDs to immediately address HOS violations.

CHAPTER 5. DISCUSSION

Table 11 shows the combined strategies used by the nine fleets to improve and maintain their safety performance. The strategies listed in Table 11 are not intended be a comprehensive list of the safety programs at the nine carriers. Rather, Table 11 displays the strategies each CMV fleet believed was critical to their improved safety outcomes.

Table 11. Haddon Matrix of Successful Safety Programs

	Vehicle	People	Environment	Management Culture
Pre-crash	<ul style="list-style-type: none"> • AEB • LDW • Blind spot detection • RSC and ESC • Speedgauge • Speed limiters • Video-based OSM systems • Monitor wear and tear • Replace parts when issues arise • 24 hour a day maintenance shop • Service tractors before 10,000 miles • Service trailers every 30 days • Inspect truck and trailer each time it returns to facility • Load specific pre-trip checklists 	<ul style="list-style-type: none"> • Participant in FMCSA’s PSP • Require previous driving experience • On-the-job training for all drivers • Finishing program for new drivers • New hire mentoring • Face-to-face interview • Hiring criteria for involvement in previous crashes • Hiring criteria for previous citations and inspections • Past Employer referrals • Driver referrals • Driving simulator assessment • Driving simulator training • Online training • Hair drug testing • Physical fitness/agility test • Safety pledge • Monthly or quarterly in-person safety meetings • Coaching sessions based on OSM data 	<ul style="list-style-type: none"> • Visible safety pledge signage in terminals • Plan routes for 45 mph average • Mandatory stops in bad weather • Schedule routes based on individual sleep patterns • Monitoring driving time in real-time 	<ul style="list-style-type: none"> • Non-monetary safety awards • Monetary safety bonuses • Frequency safety communication • Positive, non-confrontational coaching sessions • Open door policy • Full-time trainers to maintain consistent safety message • Management buy-in to safety programs • Zero tolerance for HOS violations • Ownership/top management safety communication • Driver scorecards • Family events • Encourage family involvement in safety • Family culture • Progressive discipline policy • Internal and external safety benchmarking • Share key carrier-wide crash and incident data with drivers • Share carrier-wide safety cost data with drivers • Accountability for safety in all departments • Wellness checks on drivers • Educating all department on their impact on safety • Health and wellness program • Drivers collaborate to develop safety strategies
At scene				<ul style="list-style-type: none"> • Support driver at scene
Post-crash	<ul style="list-style-type: none"> • Vehicle repair or replacement 	<ul style="list-style-type: none"> • Post-incident one-on-training • Progressive discipline policy based on crash causes • Health and wellness checks 		<ul style="list-style-type: none"> • Use of video-based OSM to find identify objective data on crash causes • Use of video-based OSM data for driver exonerations • Internal tracking of crashes for data analysis • Internal and external benchmarking • Driver incident reporting system

There was consistency across the nine carriers in terms of countermeasures viewed as important to improved safety outcomes. Six of the nine carriers indicated an improved safety culture played a significant role in improvement of their safety. Similarly, six of the nine carriers indicated the adoption of at least one advanced safety technology significantly contributed to the improved safety outcomes. Two carriers reported the importance of stringent hiring criteria as critical reasons for improved safety, and one carrier believed improved and enhanced driver training resulted in improved safety outcomes.

As shown in Table 11, the vast majority of safety countermeasures (59 out of 69) used by the nine carriers fell into the pre-crash category. Further, a large portion of safety countermeasures focused on the management culture. This supports prior literature that indicated the connection between a carrier's safety culture and safety performance.^(3,8,9)

The importance of top management buy-in was something that carriers believed was necessary to develop a successful safety culture. These results support the best practices described in Short et al. and Bergoffen et al.^(9,10) All employees in the organizations (not just drivers) should participate in safety training and education. Several carriers reported generating buy-in from other departments within the organization, such as the operations department, dispatch, and top management. Most of the carriers reported using safety bonuses and/or driver scorecards as an incentive/reward program to encourage safe driving. All carriers reported maintaining an open door policy to discuss safety-related issues and informed drivers about the carrier's safety culture during driver orientation. Finally, most of the carriers indicated the importance of keeping a positive, collaborative environment to encourage drivers to help each other and personally identify strategies for improvement.

Six of the nine fleets reported that the use of advanced technologies significantly contributed to their improved safety outcomes. Many of these carriers equipped their trucks with the latest safety features in an attempt to reduce crashes. This included the use of AEB, LDW, blind spot detection, stability control systems, and video-based OSM systems. Results from these case studies support previous research on the effectiveness of these technologies in heavy vehicles.⁽¹⁴⁾ For example, Carrier G equipped its trucks with video-based OSMs and AEB and paired the technologies with data-driven coaching. As a result, Carrier G's FMCSA-reportable crash rate decreased 66.3% in 1 year. With a suite of advanced safety systems and the use of a driving simulator for training, Carrier E experienced a 35.8% decrease in FMCSA-reportable crashes. Carrier D eliminated rollovers and rear-end collisions with the use of AEB and trailer-equipped RSC. Carrier C experienced a 75% reduction in preventable crashes with a telematics device and AEB. Carrier B experienced a 31.7% reduction in its FMCSA-reportable crash rate with the full suite of collision mitigation technologies (i.e., AEB, ACC, LDW, and trailer-equipped RSC). Lastly, Carrier A experienced a 56% reduction in preventable, rear-end collisions with use of AEB.

LIMITATIONS

Although this study collected detailed information on successful strategies to improve safety performance, there were several limitations. Data were only collected from nine carriers; however, FMCSA identifies thousands of "high-risk" carriers each year. A larger study may result in additional successful and unsuccessful strategies. Further, the nine fleets in this study

only operated in the U.S. Although the strategies identified in this study can be applied by international fleets, the results may differ. Thus, an additional study is needed to investigate the effective strategies used by international fleets.

CONCLUSION

The overall message from each of the carriers was that there was no single fix, but rather that it was a comprehensive approach that improved safety outcomes. Often it takes changes throughout the organization to reduce crashes. Each of these carriers targeted safety improvements for hiring safe drivers, training current and new drivers to safely operate trucks, developing proactive management programs to encourage safe driving, building strong safety cultures to support safety, improving driver scheduling to reduce fatigue, equipping trucks with technologies designed to assist the driver, and/or ensuring the trucks are in good working condition through vehicle maintenance. However, fleets in this study noted the importance of improvements to safety culture and the implementation of advanced safety technologies to successful safety advancement.

APPENDIX A. INTERVIEW GUIDE

Thank you again for agreeing to participate in this interview to identify factors that significantly improve carrier safety performance. We will ask you a series of questions about the following categories of factors that you may have used to significantly improve safety: hiring, training, reinforcement/discipline, safety culture, dispatching, technologies, and maintenance. We will have several questions within each of these categories. Keep in mind that you are not required to respond to any questions where you do not feel comfortable providing a response. Do you have any questions before we begin?

1. To begin, can you briefly describe your current position?
2. Approximately how many drivers does your company employ?
3. Approximately how many Class 7 and 8 power units does your company operate?
4. Approximately how many drivers does your company employ?
5. Do you operate truckload or less-than-truckload?
6. Are you a private or for-hire fleet?
7. What percentage of your operation is short haul versus long haul?
8. Was there a specific event that initiated the need for your company to improve safety? If so, please explain.
9. Did your company implement any new driver hiring policies or procedures in an attempt to improve safety? This could include new age restrictions for new drivers, expanded behind the wheel testing, or tighter restrictions on the number of allowable violations on a driving record.
 - a. If so, can you describe the new hiring policies or procedures that your company implemented in an attempt to improve safety?
 - b. Do you believe that any of these contributed to your company's improved safety? If so, which ones?
 - c. When did your company implement the new hiring policies and procedures?
 - d. How did your company decide to implement these hiring policies and procedures?
 - e. Were there any challenges or barriers that your company had to overcome when implementing the new hiring policies or procedures?
 - f. Are the hiring policies or procedures still in use today? If no, please explain why.
 - g. Have these hiring policies or procedures been revised overtime? If so, how have they been revised and why?

- h. Are any of these new policies/procedures written? If so, can you provide us with a copy? Your written policies and procedures may provide other carriers with an excellent example when they are drafting their own driving hiring policies. We can remove all identifying information from the policies if you are able to provide them.

- 10. Did your company implement any new driver training policies or procedures in an attempt to improve safety? This could include frequency of training, type of training, and/or topics targeted during training.
 - a. If so, can you describe the new training policies or procedures that your company implemented in an attempt to improve safety?
 - b. Do you believe that any of these contributed to your company's improved safety? If so, which ones?
 - c. When did your company implement the new training policies and procedures?
 - d. How did your company decide to implement these training policies and procedures?
 - e. Were there any challenges or barriers that your company had to overcome when implementing the new training policies or procedures?
 - f. Are the training policies or procedures still in use today? If no, please explain why.
 - g. Have these training policies or procedures been revised overtime? If so, how have they been revised and why?
 - h. Are any of these new policies/procedures written? If so, can you provide us with a copy?

- 11. Did your company implement any new policies or procedures to encourage and reinforce safe driving behaviors or discourage and punish unsafe driving behaviors in an attempt to improve safety? This could include new safety award programs for drivers or new procedures or new criteria for driver discipline.
 - a. If so, can you describe the new reinforcement/discipline policies or procedures that your company implemented in an attempt to improve safety?
 - b. Do you believe that any of these contributed to your company's improved safety? If so, which ones?
 - c. When did your company implement the new reinforcement/discipline policies and procedures?

- d. How did your company decide to implement these reinforcement/discipline policies and procedures?
 - e. Were there any challenges or barriers that your company had to overcome when implementing the new reinforcement/discipline policies or procedures?
 - f. Are the reinforcement/discipline policies or procedures still in use today? If no, please explain why.
 - g. Have these reinforcement/discipline policies or procedures been revised overtime? If so, how have they been revised and why?
 - h. Are any of these new policies/procedures written? If so, can you provide us with a copy?
12. Did your company implement any other management practices to improve safety culture in an attempt to improve safety? This could include increased driver involvement in safety, encouraging near crash reporting, regular safety meetings, improved crash investigations or incident follow-up procedures, and driver involvement in the safety process.
- a. If so, can you describe the safety culture policies or procedures that your company implemented in an attempt to improve safety?
 - b. Do you believe that any of these contributed to your company's improved safety? If so, which ones?
 - c. When did your company implement the safety culture policies and procedures?
 - d. How did your company decide to implement the new safety culture policies and procedures?
 - e. Were there any challenges or barriers that your company had to overcome when implementing the new safety culture policies or procedures?
 - f. Are the safety culture policies or procedures still in use today? If no, please explain why.
 - g. Have these safety culture policies or procedures been revised overtime? If so, how have they been revised and why?
 - h. Are any of these new policies/procedures written? If so, can you provide us with a copy?
13. Did your company implement any new dispatching practices in an attempt to improve safety? This could include new routing, scheduling policies, bio mathematical fatigue scheduling.

- a. If so, can you describe the new dispatching policies or procedures that your company implemented in an attempt to improve safety?
 - b. Do you believe that any of these contributed to your company's improved safety? If so, which ones?
 - c. When did your company implement the new dispatching policies and procedures?
 - d. How did your company decide to implement these new dispatch policies and procedures?
 - e. Were there any challenges or barriers that your company had to overcome when implementing the new dispatching policies or procedures?
 - f. Are the dispatching policies or procedures still in use today? If no, please explain why.
 - g. Have these dispatching policies or procedures been revised overtime? If so, how have they been revised and why?
 - h. Are any of these new policies/procedures written? If so, can you provide us with a copy?
14. Did your company implement any new technologies, including technologies that were not specifically targeting safety (e.g., technologies to improve fuel economy)? This could include automatic emergency braking, onboard monitoring systems, speed limiters, and/or global positioning systems.
- a. If so, can you describe the new technologies that your company implemented in an attempt to improve safety?
 - b. Do you believe that any of these contributed to your company's improved safety? If so, which ones?
 - c. When did your company implement the new technologies?
 - d. How did your company decide to implement new technologies?
 - e. Were there any challenges or barriers that your company had to overcome when implementing the new technologies?
 - f. Are the technologies still in use today? If no, please explain why.
 - g. Are you currently using additional technologies? If so, which ones and why were they chosen?
15. Did your company implement any new maintenance practices in an attempt to improve safety? This could include the use of new equipment maintenance tracking programs, more frequent maintenance inspections, and/or more frequent equipment turnover.

- a. If so, can you describe the new maintenance policies or procedures that your company implemented in an attempt to improve safety?
 - b. Do you believe that any of these contributed to your company's improved safety? If so, which ones?
 - c. When did your company implement the new maintenance policies and procedures?
 - d. How did your company decide to implement these new maintenance policies and procedures?
 - e. Were there any challenges or barriers that your company had to overcome when implementing the new maintenance policies or procedures?
 - f. Are the maintenance policies or procedures still in use today? If no, please explain why.
 - g. Have these maintenance policies or procedures been revised overtime? If so, how have they been revised and why?
 - h. Are any of these new policies/procedures written? If so, can you provide us with a copy?
16. Are there any other factors that may have contributed to your improved safety performance? If so, please explain.
17. What measures or key performance indicators (KPIs) does your company use to assess the effectiveness of the safety interventions?
18. Did your company implement any interventions that did not improve your safety performance? If yes, please describe the safety interventions that were not effective.
19. In general, what do you believe had the greatest impact in improving your company's safety performance? Please explain.
20. Do you have any other comments you would like to share with us today?

Thank you so much for sharing your experience and opinions with us today. Please let us know if you have any questions or if you would like to share any further information. We hope you enjoy the rest of your day.

REFERENCES

1. Federal Motor Carrier Safety Administration (2019). *Status of High Risk Carrier Investigations*. Washington, D.C.: Federal Motor Carrier Safety Administration.
2. Knipling, R.R., Hickman, J.S., & Bergoffen, G. (2003). *Synthesis 1: Effective Commercial Truck and Bus Safety Management Techniques*. Washington, D.C.: Transportation Research Board of the National Academies.
3. Corsi, T.M., & Barnard, R.E. (2003). *Best Highway Safety Practices: A Survey About Safety Management Practices Among the Safest Motor Carriers*. Washington, D.C.: Federal Motor Carrier Safety Administration.
4. Federal Motor Carrier Safety Administration (2019). *Analysis Brief: Safety Analysis and Industry Impacts of the Pre-Employment Screening Program (PSP)*. Washington, D.C.: Federal Motor Carrier Safety Administration.
5. Knipling, R.R., Boyle, L.N., Hickman, J.S., York, J.S., Daecher, C., Olsen, E.C.B., & Prailey, T.D. (2004). *CTBSSP Synthesis 4: Individual Differences and the "High-Risk" Commercial Driver*. Washington, D.C.: Transportation Research Board of the National Academies.
6. Stock, D. (2011). *I-95 Corridor Coalition Field Operational Test 10: Coordinated Safety Management; Volume I: Best Practices in Motor Carrier Safety Management*. University Park, PA: Penn State.
7. Hickman, J.S., Knipling, R.R., Hanowski, R.J., Wiegand, D.M., Inderbitzen, R.E., & Bergoffen, G. (2007). *CTBSSP 11: Impact of Behavior-Based Safety Techniques on Commercial Motor Vehicle Drivers*. Washington, D.C.: Transportation Research Board of the National Academies of Science.
8. Camden, M.C., Hickman, J.S., & Hanowski, R.J. (2015). *Effective Use of Commercially Available Onboard Safety Monitoring Technologies: Guidance for Commercial Motor Vehicle Carriers*. Report No. 15-UT-032. Blacksburg, VA: The National Surface Transportation Safety Center for Excellence.
9. Bergoffen, G., Short, J., Inderbitzen, B., Daecher, C. (2007). *CTBSSP Synthesis 12: Commercial Motor Vehicle Carrier Safety Management Certification*. Washington, D.C.: Transportation Research Board of the National Academies of Science.
10. Short, J., Boyle, L., Shackelford, S., Inderbitzen, B., & Bergoffen, G. (2007). *CTBSSP Synthesis 14: The Role of Safety Culture in Preventing Commercial Motor Vehicle Crashes*. Washington, D.C.: Transportation Research Board of the National Academies.
11. Heitmann, A., Guttkun, R., Croke, D., Moore-Ede, M. (2005). *Innovative fatigue management approach in the trucking industry*. Proceedings of the Third International

Driving Symposium on Human Factors in Driver Assessment, Training and Vehicle Design, Rockport, ME.

12. Knipling, R.R., & Bergoffen, G. (2011). *CTBSSP 20: Potential Safety Benefits of Motor Carrier Operational Efficiencies*. Washington, D.C.: Transportation Research Board of the National Academies.
13. Belzowski, B.M., Blower, D., Woodrooffe, J., & Green, P.E. (2009). *Tracking the Use of Onboard Safety Technologies Across the Truck Fleet*. (Report No. UMTRI 2009-22). Ann Arbor, MI: University of Michigan Transportation Research Institute.
14. Hickman, J.S., Guo, F., Camden, M.C., Medina, A., Campbell, J.L., Hanowski, R.J., Mabry, E., Brown, J., Richard, C., & Salyer, D. (2013). *Onboard Safety System Effectiveness Evaluation Final Report*. Report No. FMCSA-RRT-12-012. Washington, DC: Federal Motor Carrier Safety Administration.
15. Murray, W., Newnam, S., Watson, B., Davey, J., & Schonfeld, C. (2003). *Evaluating and Improving Fleet Safety in Australia*. Canberra, ACT, Australia: Australian Transport Safety Bureau.
16. Murray, W., Ison, S., Gallemore, P., & Nijjar, H.S. (2009). Effective occupational road safety programs: A case study of Wolseley. *Transportation Research Record*, 2096, 55-64. DOI: 10.3141/2096-08
17. Ritchie, J., Spencer, L., & O'Conner, W. (2003). Carrying out qualitative analysis. In J. Ritchie & J. Lewis (Eds.), *Qualitative Research Practice*. London: Sage.