Safety Science 120 (2019) 589–602

Contents lists available at ScienceDirect

Safety Science

journal homepage: www.elsevier.com/locate/safety

The relationships among roadway safety management practices, collision rates, and injury rates within company fleets

Jonathon M. Vivoda[a,*], Stephanie G. Pratt[b], Susan J. Gillies[c]

[a] Department of Sociology and Gerontology, Upham Hall, 100 Bishop Circle, Miami University, Oxford, OH 45056, USA
[b] National Institute for Occupational Safety and Health, Division of Safety Research, 1095 Willowdale Road, Mail Stop H-1808, Morgantown, WV 26505, USA
[c] Network of Employers for Traffic Safety, 344 Maple Avenue West #357, Vienna, VA 22180, USA

ARTICLE INFO

Keywords:
Fleet safety
Work-related crashes
Motor vehicle crashes
Injury
Policy
Practice
Exposure-adjusted

ABSTRACT

Motor vehicle crashes (MVCs) are consistently the leading cause of work-related fatalities for all industries combined. They comprise the majority of workplace fatalities for occupations involved in transportation/material moving and are one of the leading causes of death for many occupations which involve driving, but where driving is not the primary job duty. Nonfatal work-related MVCs also have substantial injury and economic consequences for workers and employers. This study used data from 70 companies from a range of industries to assess the relationship between companies' self-reported fleet safety management practices/policies and collision/injury metrics. Several practices were found to be statistically significantly related to collision/injury metrics, including mobile phone record checking, fatigue mitigation practices, provision of driver training, and collision response procedures. Implications of these findings and suggestions for future research are discussed.

1. Introduction

The risk of involvement in a work-related motor vehicle crash (MVC) affects millions of workers in the United States (U.S.). MVCs are the leading cause of work-related fatalities for all industries combined. Of 66,588 work-related fatalities reported by the Census of Fatal Occupational Injuries (CFOI) between 2003 and 2015, 30% (n = 19,648) were due to MVCs on or off a public roadway fatal to a driver or passenger, and an additional 6% (n = 4217) were pedestrians struck by motor vehicles (Bureau of Labor Statistics 2017a).[1] By occupation, MVCs made up the majority of workplace fatalities for workers engaged in transportation and material moving, accounting for 66% of the total in 2015. They are also a leading cause of death for many occupations that involve driving, but where driving is not the primary job duty, e.g., managers and sales workers (Bureau of Labor Statistics, 2017b).

Nonfatal work-related MVCs also have substantial injury and economic consequences for workers and employers. For roadway incidents involving a motorized land vehicle, an estimated 31,130 private-industry workers who were a vehicle driver or passenger sustained lost-workday injuries in 2015 (Bureau of Labor Statistics, 2016). Nearly 60% of these were serious enough to result in six or more lost workdays, and 33% of the total resulted in 31 or more lost workdays. For non-roadway incidents involving a motorized land vehicle, an estimated 6930 workers who were a vehicle driver or passenger sustained lost-workday injuries, 34% of which resulted in 31 or more days away from work (Bureau of Labor Statistics, 2016). Further, the Liberty Mutual Workplace Safety Index estimated that serious roadway incidents involving motorized land vehicles resulted in $3.2 billion in workers' compensation costs in the U.S. in 2015 (Liberty Mutual Insurance Company, 2018). In 2013, an on-the-job crash involving a nonfatal injury was estimated to cost the employer almost $65,000 on average, regardless of liability (Network of Employers for Traffic Safety, 2015).

In the U.S., "work-related" MVC s are limited to those that occur only during the use of a vehicle for company business during the course of the business day, regardless of whether the vehicle was owned or

* Corresponding author.
E-mail address: vivodajm@miamioh.edu (J.M. Vivoda).

[1] As defined by the Bureau of Labor Statistics, work-related MVCs comprise three broad categories: (1) *Roadway incidents involving a motorized land vehicle* are "events involving transportation vehicles under normal operation, on roadways, which includes the parts of the public highway, street, or road normally used for travel, as well as the shoulder or surrounding areas, telephone poles, bridge abutments, trees aligning roadway, etc.;" (2) *Non-roadway incidents involving a motorized land vehicle* "closely mirror the coding scheme for roadway incidents, but include only those instances that occur entirely off of a public roadway, such as in a field, factory, or parking lot;" and (3) *Pedestrian vehicular incidents* include "pedestrians and other nonoccupants of vehicles who are struck by vehicles or other mobile equipment in normal operation regardless of location."

https://doi.org/10.1016/j.ssci.2019.07.033
Received 7 December 2018; Received in revised form 24 June 2019; Accepted 25 July 2019

leased by the company or the employee's personal vehicle (often referred to as a "grey fleet" vehicle) (Bureau of Labor Statistics, 2012). However, companies provide vehicles to employees under conditions that are broader than the scope of "work-related" crashes or injuries reported in national statistics. Employees may be issued vehicles that are authorized for business use, for commuting to or from work, for personal use, or for use by family members. Use of vehicles under all these conditions means that: (1) for company-provided vehicles, companies' assumption of vehicle liability extends beyond the work day; and that (2) liability also extends to "grey fleet" vehicles. Taken together, company-provided vehicles (regardless of how they are used) and "grey fleet" vehicles may be referred to as a company's "fleet" – in other words, all the vehicles that are operated on company business or for which the company assumes liability.

A number of resources are available to guide companies in managing road risk for employees, as described below. All these resources recommend a comprehensive road safety management program as essential to preventing MVCs involving fleet vehicles. Within such a program, progress toward road safety performance goals may be assessed by: (1) supplementing ongoing collection and analysis of collision data by checking to ensure that the processes in place to prevent MVCs are being implemented as planned (often referred to as an internal audit); and (2) benchmarking road safety management processes and/or outcomes with other organizations [see, for example, (European Transport Safety Council, 2012, Mitchell et al., 2012, National Transport Commission (Australia) and Accident Compensation Corporation (New Zealand), 2013, Network of Employers for Traffic Safety, 2014, Pratt and Rodríguez-Acosta, 2015)]. U.S. and international consensus standards for fleet safety management include similar provisions regarding data collection, auditing, and benchmarking (International Organization for Standardization, 2012, ANSI/ASSP, 2017a).

Research has also identified the importance of placing a road safety management program (indeed, any program intended to manage a specific workplace health or safety hazard) within the context of the company's overall occupational safety and health (OSH) management system. The rationales for this integration across programs include: sustained competitive advantage as a result of reductions in injury, illness, and absenteeism (Loeppke et al., 2015, Wachter and Yorio, 2014); a shared vision that values OSH on the same level as operational and production goals (Loeppke et al., 2015); avoiding OSH management "silos" through actions that bring together risk management, safety management, operations management, and human resources (Hymel et al., 2011, Loeppke et al., 2015, Sorensen et al., 2013); opportunity for increased engagement with workers on OSH issues (Loeppke et al., 2015, Sorensen et al., 2013, 2018); and opportunity to apply safety and health messaging on the same topic to the on-and off-the-job contexts (Hymel et al., 2011, Sorensen et al., 2013, 2018). Similarly, a U.S. national consensus standard for OSH management systems calls not only for integration of components of the OSH management system, but integration of the OSH management system with management of quality, environment, and other areas (ANSI/ASSP, 2017b).

Benchmarking across organizations to compare operational costs, freight rates, customer service, and supply-chain efficiency is a well-established management tool in the truck transportation sector [see, for example, (Menachof and Wassenberg, 2000, Ozkaya et al., 2010, Woodrooffe et al., 2010, Torrey and Murray, 2015)]. However, few of these sources incorporated road safety indicators. Two related studies from Australia are an exception to this. The first of these identified road safety policies and practices shown by research to be effective in managing MVC in heavy-vehicle transport (Mooren et al., 2014a), examining studies that used both the organization and the individual driver or manager as the unit of analysis. This paper reported that organization-level studies most often found the following elements to be associated with reduced crash or injury risk: safety training; management commitment to road safety; scheduling and journey planning; communication and support; vehicle conditions and physical work environment; risk analysis and corrective actions; and incentives. Although this study did not provide a ready-to-use benchmarking tool, the processes shown to be effective could be the basis for a tool to benchmark trucking safety. The second Australian study built on the findings of Mooren et al., 2014a, examining trucking companies with high and low rates of insurance claims according to their implementation of evidence-based program elements (Mooren et al., 2014b). As was hypothesized, companies with lower claims rates were more likely to have policies and practices aligned with those identified by Mooren et al. (2014a): risk assessment, including on-site safety audits; journey management procedures; centralized scheduling and rostering; incentives to drivers who proposed safety innovations; and support for driver input into occupational safety and health. There were, however, some counter-intuitive findings. For example, having pre-hiring screening practices in place and having fatigue management policies were associated with higher claims rates (Mooren et al., 2014b).

Several organizations have designed benchmarking programs and tools applicable to all types of company fleets, including the Australia-based National Road Safety Partnership Program (NRSPP) (Mooren, 2015, www.nrspp.org.au), the Occupational Road Safety Alliance in the United Kingdom (www.fleetsafetybenchmarking.net/main/), and the U.S.-based global non-governmental organization the Network of Employers for Traffic Safety (NETS); www.trafficsafety.org) To date, the NRSPP is the only one of these benchmarking programs discussed in the peer-reviewed literature. The NRRSP's content areas guided semi-structured interviews with 83 individuals with road safety management responsibilities, with the overall aim of gauging the extent to which these individuals' organizations addressed these content areas in their road safety policies (Warmerdam et al., 2017). The main conclusions pointed to a lack of policies to address known risk factors for workplace crashes such as fatigue, lack of clarity on safety roles and responsibilities for managers and drivers, inadequate policies for initial driver qualification and maintaining driver competence, and potential pitfalls of relying on technology over person-to-person communication and feedback.

Another framework, developed to audit safety management in light-vehicle fleets, could also be used to benchmark processes across organizations (Mitchell et al., 2012). Development of this audit tool began with a literature review to identify best practices, followed by interviews with a small number of fleet managers and drivers to assess the relevance of these best practices and potential usefulness of the tool. Within the tool, best practices were grouped into five topic areas: management, systems, and processes; monitoring and assessment; employee recruitment, training and education; vehicle technology, selection and maintenance; and vehicle journeys. One feature of this audit tool that would make it valuable for benchmarking is that for each program component (for example, management commitment to safety), four levels of performance are delineated, including a description of the policies that must be in place to achieve each level of performance.

Despite the availability of road safety benchmarking resources for companies, peer-reviewed literature that reports benchmarking results is limited. Case studies in the peer-reviewed literature have reported the use of ongoing data collection and analysis as an internal tool for fleet safety monitoring and continuous improvement (Darby et al., 2009, Darby et al., 2011, Murray et al., 2012, Wallington et al., 2014). Although studies such as these noted that benchmarking with other organizations was a component of the collaborating company's road safety management strategy (Murray et al., 2012, Wallington et al., 2014), they reported no results from external benchmarking.

In addition to the limited number of analyses of road safety benchmarking data, no studies other than Mooren et al. (2014b) could be found in the peer-reviewed literature that have assessed the relationships between road safety program elements and road safety outcomes at organization level. Most of the existing literature has focused on describing fatal crashes within specific industries [see, for example, (Ore and Fosbroke, 1997, CDC, 2003, Retzer et al., 2013, Tiesman et al., 2013)], with relatively few analyses addressing MVCs involving light vehicles operating for business purposes. Finally, with the exception of studies on heavy trucks [see, for example, Campbell, 1991, Lyman and Braver, 2003, Fowles et al., 2013, Cantor, 2014, Guest et al., 2014, Federal Motor Carrier Safety Administration, 2017)] and one study based on data from a single light-vehicle fleet (Pratt and Bell, 2019), most previously-published research has calculated collision or injury rates based on the number of workers [see, for example, (Mitchell et al., 2004, Driscoll et al., 2005, Pratt and Rodríguez-Acosta, 2013, Retzer et al., 2013, Chen et al., 2014)] instead of vehicle miles traveled (VMT), which is a better measure of exposure to MVC risk (Morris, 2015).

The study reported here attempts to address several gaps in the literature: (1) the lack of peer-reviewed literature that reports results of road safety benchmarking across multiple organizations; (2) the limited number of studies that establish a link between positive road safety outcomes in organizations and specific elements of road safety management programs; and (3) the limited number of studies that report rates of work-related crashes (following the U.S. definition) or MVCs in company fleets based on driving exposure. This study reports benchmarking results from NETS for the first time in the peer-reviewed literature, using data from companies from diverse industries that operate all vehicle types; calculates collision and injury rates using VMT as the measure of driving exposure; and links program elements to three safety outcomes: collisions per million miles traveled (CPMM), collisions per 100 vehicles (%Fleet), and injuries per million miles traveled (IPMM).

1.1. Hypotheses

The primary aim of this study was to determine which organizational practices and policies were significantly related to the fleet safety outcomes assessed in this study. In addition, analyses also allowed for hypothesis testing related to the number of practices/policies in place, and the strength of the consequences of safety violations. Specifically, the analysis was guided by the following hypotheses:

H1. Companies with greater numbers of fleet safety program elements in place (either overall or in response to a specific safety issue) will have better fleet safety outcomes: lower CPMM, %Fleet, and IPMM.

H2. Companies with stronger consequences for violations of policies on specific road safety issues will have better fleet safety outcomes: lower CPMM, %Fleet, and IPMM. For example, companies for whom violation of a mobile phone policy is potential grounds for termination will have better outcomes than companies that discourage mobile phone use while driving but apply no consequences.

2. Methods

The data used for this study were provided by NETS, a not-for-profit membership organization consisting of company-based road safety professionals, whose mission is to reduce traffic-related collisions, injuries, fatalities, and costs around the world. Each year, NETS conducts the STRENGTH IN NUMBERS® Fleet Safety Benchmark Program, which allows member companies to compare their performance against other companies, learn which program elements distinguish the highest-performing companies, and discuss benchmark results and best practices in a collegial environment. In addition to submitting collision and injury data, benchmark participants self-report the presence or absence of specific fleet safety practices and policies in their companies via a questionnaire. Consistent with preferred practice (Callen and Wilson, 2015), the results of the data analyses are discussed at an annual conference.

Table 1
Vehicle use scenarios reported by 2016 NETS benchmark participants, U.S. fleet only.

Vehicle Use Scenario[1]	Companies (n = 70)	
	#	%
Employees driving company-owned or -leased vehicles on company business	70	100.0
Employees driving personal vehicles on company business	28	40.0
Employees driving rental vehicles on company business	31	44.3
Company "pool" vehicles that are not assigned to individual employees	37	52.9
Executives driving company vehicles (may include use by family members)	35	50.0
Use of company vehicles by authorized employees or family members on personal time	33	47.1
Family members driving company vehicles (even if unauthorized)	24	34.3

[1] Contractor vehicles were excluded from data collection.

Participants with multi-national operations may report data for multiple countries, but the analysis reported here is limited to U.S. fleets. Of 120 member companies, a total of 71 (59%) companies submitted benchmarking data for 2016. One company did not report U.S. data separately and was therefore excluded from the analysis. NETS benchmarking data covered several different vehicle use scenarios (Table 1). It should be noted that the range of these scenarios extends beyond the types of use that are within the scope of a work-related crash as defined in the U.S., in that they limited use of company-provided vehicles by the employee or family member for personal travel. All companies reported data (including collisions, injuries, and vehicle mileage) for employees who drove company-owned or -leased vehicles on company business, with smaller proportions reporting data for one or more other scenarios. The 28 companies reporting that their data included personal vehicles used by employees on company business were also asked to estimate the percentage of personal vehicles in their fleets. Only 4 of the 28 companies estimated that this was more than 10% of vehicles, and for most of the remaining 24 companies it was well under 5%. Of note, three of the scenarios reported involved potential use of vehicles by employees' family members. The study data include collisions, injuries, and mileage associated with these types of vehicle uses. The inclusion of personal and family mileage disproportionately affected light passenger vehicles – not medium and heavy vehicles, which were unlikely to have been used by anyone other than the employee and unlikely to have been driven for personal travel.

The NETS benchmarking program collects data needed to calculate CPMM, %Fleet, and IPMM. A collision was defined as a single- or multiple-vehicle event that occurred on or off a public roadway, or an event in which a vehicle struck another road user such as a pedestrian or cyclist. A single vehicle overturning or rolling over was also considered a collision. Events not classified as collisions were: acts of nature, collisions with animals or debris, an object hitting the vehicle, damage to glass only, vandalism, fire, theft, vehicle failure, and the vehicle being hit while parked.

Collisions that occurred while the employee driver was operating a company-owned or -leased vehicle or an executive vehicle may have taken place in any of these circumstances: (1) driving for work during the business day; (2) commuting to or from work; or (3) personal travel as authorized by the company. For company-leased vehicles only, collision data did not distinguish between those involving the employee driver and those involving a family member. Further, for company-owned or -leased vehicles and executive vehicles, vehicle mileage data did not distinguish between miles associated with driving for work during the business day, commuting, and personal travel, nor did they distinguish between miles driven by the employee and the family member. It should be noted, however, that as the last two rows of Table 1 show, these issues did not affect all companies in the study, and that it is reasonable to assume that most of the vehicle mileage was contributed by employee drivers.

The NETS injury definition is equivalent to the definition of a work-related injury used by the U.S. Occupational Safety and Health Administration (OSHA). These "OSHA-recordable" injuries encompass: fatalities; injuries that resulted in loss of consciousness, days away from work, restricted work, or transfer to another job; and injuries requiring medical treatment beyond first aid (Occupational Safety and Health Administration, 2017). Consistent with this U.S. definition of a work-related injury, injuries reported here do not include those that occurred while commuting to or from work.

Benchmark participants reported number of vehicles, collisions, and VMT for the following vehicle sizes:

- Light: ≤10,000 lb (≤4536 kg) (SUVs, sedans, light pick-up trucks, passenger vans)
- Medium: 10,001–26,000 lb (4536–11,793 kg)
- Heavy: > 26,000 lb (> 11,793 kg)

NETS also collects data on 2- and 3-wheeled vehicles and vehicles used primarily on a work site; these were excluded from this analysis.

CPMM was calculated by multiplying the total collisions reported within each company by 1,000,000 and then dividing by the total miles traveled by all vehicles reported. IPMM was calculated the same way as CPMM, with reported injuries replacing collisions in the formula. % Fleet was calculated by dividing the total number of collisions reported by each company by the number of vehicles reported, and then multiplying by 100. The same formulas were used to calculate CPMM, % Fleet, and IPMM separately for light, medium, and heavy vehicles.

Collision and injury metrics were supplemented with results from the questionnaire about members' fleet safety programs and practices. The nature and level of individuals responding to the questionnaire varied across companies. In general, those who responded to questions about fleet safety programs and practices were higher-level managers; some were fleet safety program managers or fleet asset managers, while others had broad OSH responsibilities. Individuals who compiled and submitted the collision, injury, vehicle, and mileage metrics were more likely to be mid-level analysts with knowledge and experience with the NETS data requirements and conventions.

Company representatives responded to questions about various fleet safety topics, including:

- Fleet safety management system:
  - o Age of the program and recent changes to the program
  - o Tracking of road safety metrics
  - o Motor vehicle record checks
  - o Level of road safety support from executive team, and level of performance of field managers
  - o Inclusion of road safety performance in managers' performance review
  - o Drivers' receipt of information on road safety performance at the individual or company level
  - o Collision review and response process, including determination of severity based on criteria for cost, damage, or injury
  - o Green fleet practices
- Fleet safety interventions:
  - o Processes for identifying and mitigating high-risk driving
  - o Driver training, commentary drives (supervisor "ride-alongs")
  - o Fatigue risk management (FRM)
  - o Mobile phone policies
  - o Use of in-vehicle monitoring systems (IVMS)
  - o Procurement of company vehicles with collision avoidance technologies

To address Hypothesis 2 (i.e., that companies with stronger consequences for violation of road safety policies will have better fleet safety outcomes), several questions were utilized to determine the strength with which these program elements were implemented. For one set of questions – those related to fatigue risk management (FRM) – companies were asked to provide separate responses by vehicle size (light, medium, or heavy), because of potential program differences due to regulatory requirements.

For items where companies identified multiple company practices related to a given issue (e.g., FRM), composite variables were created by summing the total number of related practices, representing stronger responses to that issue. A variable was also created to represent overall road safety within the companies, by weighting major program topic areas such that the best possible implementation would result in a value of one. Weighting was done because some topic areas had more items on the questionnaire than others. These values were then summed across the major topic areas. Finally, mutually exclusive but separate, related items were also combined into single variables to allow for direct comparison between the different practices. The Appendix A provides a complete list of items assessed in the questionnaire.

2.1. Data management and analysis procedures

All data were read into SAS version 9.4 and assessed for out-of-range errors and any other problems. Descriptive statistics were generated for each individual variable, including means and frequencies, as appropriate. Histograms were also generated to assess the distribution of key outcomes of interest. The data were also assessed for outliers, and for influential outliers in particular. To assess these issues, boxplots for each outcome were generated and examined. In addition, preliminary regression models were fit and influence statistics and plots were generated, including Cook's distance, leverage and outlier plots, DFFITS, and DFBETAs. These diagnostics assess whether removing a particular observation results in a major change to the estimates, thus rendering that observation unduly influential. Assessment of these analyses resulted in the removal of two companies for analyses involving CPMM, and one each for analyses involving %Fleet and IPMM.

Bivariate relationships were assessed between the three outcomes of interest, as were the relationships between each company practice and each of the three outcomes. Independent samples t-tests, Pearson correlations, and one-way analysis of variance (ANOVA) tests were conducted as appropriate. A significance level cut-off of $p < 0.05$ was used for all analyses. Items related to fatigue mitigation practices, to which companies provided separate responses by vehicle size, were analyzed by CPMM, %Fleet, and IPMM specific to each vehicle size.

Linear regression techniques were also used to assess each of the outcomes, fitting a separate model for each. The likelihood of practices to co-occur in given companies and the limited number of companies available in the dataset limited the scope of the regression analyses. Only practices related to companies' U.S. fleets as a whole were considered for the regression models, to avoid data loss due to listwise deletion. All practices that were significant ($p < 0.05$) in the bivariate context were initially considered as regression predictors. For issues represented by multiple related items, only the most statistically

Table 2
Fleet characteristics for 2016 NETS benchmark participants, U.S. vehicles only.

Companies by industry[1]	Number	Percentage
Total	70	100.0
Pharmaceutical	16	22.9
Other manufacturing[2]	13	18.6
Utilities	9	12.9
Oil & gas extraction	6	8.6
Insurance	5	7.1
Professional, scientific, and technical services	9	12.9
Other services[3]	6	8.6
Transportation and warehousing	5	7.1
Retail trade	1	1.4
Fleet vehicle use[4]		
Sales	47	67.1
Transport of products/materials	39	55.7
Service	36	51.4
Executive use	33	47.1
Maintenance	32	45.7
Transport people	19	27.1

Vehicle size	Number	Percentage	Total miles	Miles/vehicle
Total [70 companies]	332,846	100.0	5,474,336,976	16,447
Light (≤10,000 lb) (≤4536 kg) [66 companies]	262,232	78.8	4,140,101,527	15,788
Medium (10,001–26,000 lb) (4536–11,793 kg) [26 companies]	46,959	14.1	545,827,849	11,623
Heavy (> 26,000 lb) (> 11,793 kg) [29 companies]	23,655	7.1	788,407,600	33,329

1 North American Industry Classification System (NAICS) (2017). [https://www.census.gov/cgi-bin/sssd/naics/naicsrch?chart=2017].
2 Excludes Pharmaceutical.
3 Excludes Insurance and Professional, scientific, and technical services.
4 Does not sum to 70 companies; many companies operate vehicles for a range of purposes. Responses to this item cover both U.S. and global operations.

significant (e.g., smallest *p*-value) factor, or the one that most universally represented the issue (e.g., sum of fatigue mitigation practices, combined mobile phone policy variable) was included as a predictor, to avoid problems with multicollinearity. These items were all entered into initial models (one for each of the three outcomes) and assessed. Predictors with the highest *p*-values were removed first, and the models were then re-fit. That iterative process was followed until a model was finalized for each outcome.

3. Results

Fleet characteristics for the NETS member companies are shown in Table 2. A variety of industries are represented, with a particularly strong representation of pharmaceutical and manufacturing companies.

Table 3
Descriptive statistics for outcomes of interest by vehicle size.

Outcome	*n*	M	*sd*	Min	Max
CPMM (total)	68	4.94	2.10	0.46	9.89
Light vehicles	65	4.93	2.12	0.00	9.04
Medium vehicles	24	8.37	10.55	0.00	44.63
Heavy vehicles	28	6.40	7.12	0.00	29.40
%Fleet (total)	69	10.10	5.18	0.09	20.77
Light vehicles	66	9.28	5.02	0.00	19.37
Medium vehicles	26	10.30	9.89	0.00	37.50
Heavy vehicles	28	11.01	12.89	0.00	66.67
IPMM (total)	67	0.27	0.28	0.00	1.33
Light vehicles	64	0.33	0.66	0.00	4.96
Medium vehicles	25	0.24	0.41	0.00	1.38
Heavy vehicles	28	0.17	0.26	0.00	1.05

Notes: n = number of companies; M = mean; sd = standard deviation; min = minimum value; max = maximum value.
CPMM = collisions per million miles, %Fleet = collisions per 100 vehicles, IPMM = injuries per million miles.

NETS member companies use vehicles in their fleets for a variety of purposes, with sales and transport of goods the most commonly reported. A large proportion of the vehicles reported by NETS member companies were light vehicles (78.8%), which also represented a majority of the miles traveled (over four billion). More than a quarter of NETS member companies also reported information for heavy and medium duty vehicles.

The numbers of miles driven, vehicles, and collisions varied across NETS member companies. Miles driven ranged from just over a million miles to nearly 500 million. Number of vehicles ranged from 136 vehicles to almost 51,000; collisions ranged from one to about 3100. The mean CPMM for all vehicles combined was 4.94, the average %Fleet was 10.10, and the overall mean IPMM was 0.27 (Table 3). The CPMM for light vehicles was very similar to the overall rate (Table 3) because most miles were driven by these vehicles (Table 2). Potential differences in each outcome within the three vehicle sizes were assessed using one-way ANOVAs with the Tukey correction for pairwise comparisons. Results indicated that CPMM differences between light and medium vehicles approached significance ($p = 0.051$), with no comparisons reaching the 0.05 threshold. %Fleet was similar across the vehicle sizes, with slight increases, but no significant differences, as vehicle weight increased. The rate of IPMMs was very low, given that an injury is a much less common event than a collision. There were no statistically significant differences in IPMM by vehicle size.

3.1. Bivariate results

3.1.1. CPMM and fleet safety practices t-test results

Bivariate analyses involved assessing differences in each outcome by whether or not a company reported engaging in a given fleet safety practice. Table 4 shows the means, standard deviations, and independent samples *t*-test results for statistically significant CPMM analyses. A list of all variables analyzed in this study is available in the Appendix A, but for the sake of parsimony only those with a statistically significant relationship to CPMM are presented here. Several practices

Table 4
Relationships between CPMM and fleet safety practices – significant results for independent samples t-tests.

Practice/policy	Yes			No			*t*-value
	M	*sd*	*n*	M	*sd*	*n*	
Currently (re)developing road safety program	6.02	0.59	6	4.84	2.17	62	−3.25**
High-risk drivers receive remote driver training	5.66	1.97	32	4.22	1.91	27	−2.83**
Commentary drives: behind-the-wheel	3.78	2.26	17	5.27	2.29	24	2.07*
Collision review includes determination of severity	4.13	2.05	26	5.34	1.97	36	2.34*
Fatigue risk management (LV)							
Training for new hires	1.57	0.82	4	5.15	1.98	61	3.56***
Refresher training for all drivers	3.60	2.02	11	5.20	2.05	54	2.36*
Medical screenings for fatigue	1.78	0.47	2	5.03	2.07	63	2.20*
Restrictions on night driving	2.44	1.22	4	5.09	2.06	61	2.53*
In-vehicle monitoring system (IVMS) in use	4.50	2.24	40	5.58	1.73	28	2.13*
IVMS summaries provided to upper management	5.15	2.24	23	3.63	1.99	17	−2.21*
Fleet safety scorecard: data points included							
CPMM	4.76	2.06	36	6.98	2.22	7	2.58*
Severity	3.72	1.90	14	5.79	2.07	29	3.16**
Preventable/non-preventable	5.91	1.84	24	4.12	2.30	17	−2.85**
Commentary drive completions	3.29	1.92	9	5.60	2.06	34	3.04**
Fleet safety scorecard: publishing to drivers	4.08	2.47	15	5.68	1.89	28	2.38*
Required rollover protection on new vehicles	3.57	1.94	8	5.39	2.05	52	2.35*

Notes: M = mean; sd = standard deviation; n = number of companies; LV = light vehicles.
* $p < 0.05$.
** $p < 0.01$.
*** $p < 0.001$.

were significantly associated with a difference in CPMM, as noted below. Companies that reported they were currently either developing or re-developing their road safety program had CPMMs about 1.18 points higher than those who were not, and companies that provided remote driver training (online, CD, or DVD-based training) for high-risk drivers had CPMMs about 1.44 points higher than those that did not.

Conducting commentary drives, determining severity as a part of collision reviews, using in-vehicle monitoring systems (IVMS), and requiring rollover protection on new vehicles purchased were all significantly related to lower CPMMs. Several fatigue mitigation practices were significantly related to lower CPMMs, including fatigue training for new hires (mean difference = 3.58, the largest identified with these analyses), refresher training for all drivers, medical screenings for fatigue, and placing restrictions on night driving. Companies were also asked if they created and published (internally) a fleet safety scorecard. Several aspects of the scorecard were also statistically significant. Including preventable and non-preventable collisions on the scorecard was significantly associated with higher CPMMs, but the reason for this result was unclear.

Table 5
Relationships between %Fleet and fleet safety practices – significant results for independent samples t-tests.

Practice/policy	Yes			No			*t*-value
	M	*sd*	*n*	M	*sd*	*n*	
Significant road safety program revision > 5 years ago	4.52	0.81	3	10.35	5.15	66	7.42***
Any form of driver training for all employees	5.94	4.45	10	10.81	4.99	59	2.89**
Collision review includes determination of severity	7.84	5.45	25	11.28	4.74	38	2.66*
Fatigue risk management (LV)							
Fatigue training for new hires	2.49	1.79	4	9.72	4.85	62	2.95**
Medical screenings for fatigue	2.22	0.27	2	9.50	4.94	64	2.07*
Restrictions on night driving	3.34	1.77	4	9.67	4.93	62	2.54*
Tracking near misses	8.21	5.52	24	11.11	4.75	45	2.28*
Fleet safety scorecard: near misses	5.83	4.26	8	11.27	5.08	36	3.15**
Banned use of mobile phone equipment while driving	8.19	6.16	23	10.99	4.60	28	2.02*
Driving record is checked at time of hire	5.90	1.17	6	10.50	5.24	63	5.64***

Notes: M = mean; sd = standard deviation; n = number of companies; LV = light vehicles.
* $p < 0.05$.
** $p < 0.01$.
*** $p < 0.001$.

3.1.2. %Fleet and fleet safety practices t-test results

The next analysis assessed the relationships between %Fleet and fleet safety policies and practices (Table 5). The results were similar but not identical to the CPMM findings. Again, only significant results are shown in Table 5; see the Appendix A for a list of all variables assessed. Having significantly revised the road safety program more than five years ago was related to lower %Fleet. Likewise, providing driver training for all employees, determining severity as part of collision reviews, tracking near misses (near crashes), including near misses on one's fleet safety scorecard, and checking driving records at the time of hire were all significantly associated with lower %Fleet. Similar to CPMM comparisons, several elements of FRM for light vehicles were significantly related to lower %Fleet, with the largest differences observed for fatigue training for new hires and medical screenings for fatigue, at 7.23 and 7.28 percentage points lower, respectively.

3.1.3. IPMM and fleet safety practices t-test results

Significant differences for IPMM are shown in Table 6. The largest differences were once again noted for fatigue mitigation practices applied to light vehicles, but significantly lower IPMMs were also noted for companies that applied these practices to heavy and medium vehicles. Other major themes emerging in this analysis were similar to those noted for CPMM and %Fleet. Currently revising one's road safety program was related to higher IPMMs, while having completed the last significant revision more than five years ago was associated with lower IPMMs. Driver training, remediation for high-risk drivers, determining collision severity, IVMS, several aspects of companies' fleet safety scorecard, and having a corporate executive team that champions road safety were all related to lower IPMMs. Some counter-intuitive results

Table 6
Relationships between IPMM and fleet safety practices – significant results for independent samples t-tests.

Practice/policy	*Yes*			*No*			*t*-value
	M	*sd*	*n*	M	*sd*	*n*	
Current/recent road safety program revision	0.35	0.35	30	0.20	0.19	37	−2.12*
Significant road safety program revision > 5 years ago	0.12	0.04	3	0.28	0.29	64	3.73**
Any form of driver training for new hires who will use non-company vehicles	0.17	0.11	25	0.33	0.33	42	2.87**
Any form of driver training for all employees	0.08	0.09	11	0.31	0.29	56	4.60***
High-risk (HR) drivers							
Classified via audits, observation, commentary drives	0.20	0.27	29	0.35	0.30	30	2.05*
Respond to HR classif. with classroom training	0.20	0.21	27	0.35	0.34	32	2.08*
Respond to HR classif. with behind-the-wheel training	0.21	0.25	34	0.37	0.34	25	2.00*
Collision review includes determination of severity	0.16	0.18	25	0.33	0.32	37	2.55*
Fatigue risk management							
Fatigue training for new hires (LV)	0.03	0.02	4	0.35	0.68	60	3.66***
Medical screenings for fatigue (LV)	0.04	0.01	2	0.34	0.67	62	3.56***
Restrictions on night driving (LV)	0.03	0.02	4	0.35	0.68	60	3.66***
Company standards for driving and rest hours (MV)	0.04	0.09	10	0.37	0.48	15	2.57*
Fatigue training for new hires (HV)	0.04	0.04	6	0.21	0.28	22	2.72*
Refresher training on fatigue for all drivers (HV)	0.05	0.09	11	0.25	0.31	17	2.48*
Medical screenings for fatigue (HV)	0.05	0.04	5	0.19	0.28	23	2.30*
One-on-one sessions to manage fatigue (HV)	0.04	0.03	3	0.19	0.27	25	2.59*
IVMS included driver camera(s)	0.13	0.08	10	0.30	0.30	29	2.82**
Fleet safety scorecard: data points included							
Collision-related injuries or fatalities	0.18	0.17	26	0.40	0.36	18	2.45*
Near-misses	0.12	0.11	9	0.30	0.30	35	2.87**
Collisions on company vs. personal time	0.11	0.08	8	0.30	0.30	36	3.45**
Commentary drive completions	0.12	0.10	10	0.31	0.30	34	3.14**
Driver action plan development/completion	0.15	0.11	6	0.29	0.30	38	2.11*
Costs of collisions	0.17	0.12	16	0.32	0.33	28	2.29*
Fleet safety scorecard: publishing to drivers	0.14	0.10	16	0.34	0.32	28	2.98**
Corporate executive team championed road safety	0.12	0.08	10	0.30	0.30	57	3.88***
Required anti-lock braking protection on new vehicles	0.28	0.28	58	0.04	0.04	3	−6.37***
Driving record is not checked	0.07	0.11	6	0.29	0.29	61	3.91**

Notes: M = mean; sd = standard deviation; n = number of companies; LV = light vehicles; MV = medium vehicles; HV = heavy vehicles.
* $p < 0.05$.
** $p < 0.01$.
*** $p < 0.001$.

Table 7
Relationships between outcome measures and fleet safety practices – significant results for Pearson correlations.

Practice/policy	Outcome					
	CPMM		%Fleet		IPMM	
	r	*n*	*r*	*n*	*r*	*n*
# fatigue mitigation practices (LV)	−0.29*	65	−0.34**	66	*n.s.*	64
# fatigue mitigation practices (all vehicle sizes)	*n.s.*	68	−0.33**	69	*n.s.*	67
Mobile phone policy (higher = stronger policy)	*n.s.*	61	−0.25*	61	*n.s.*	61
Field managers' performance on road safety	−0.33†	35	*n.s.*	36	−0.39*	36

Notes: M = mean; sd = standard deviation; n = number of companies; LV = light vehicles.
***$p < 0.001$.
† $p = 0.051$.
* $p < 0.05$.
** $p < 0.01$.

were also observed. For example, companies that did not check driving records reported lower IPMMs, while companies that reported anti-lock brakes were a requirement for new vehicle purchases reported higher IPMMs.

3.1.4. CPMM, IPMM, and %Fleet correlation and ANOVA results

To test Hypothesis 1 (that companies with greater numbers of fleet safety program elements would have better fleet safety outcomes), correlations between each outcome and the composite variables created to represent overall road safety, and road safety within each topic area, were also conducted. The expected inverse relationship was observed between the overall composite variable and each of the outcomes, but none of these relationships were statistically significant (CPMM: $r = -0.17$, $p = 0.30$; %Fleet: $r = -0.13$, $p = 0.31$; IPMM: $r = -0.13$, $p = 0.29$). Significant results of additional Pearson correlations are shown in Table 7, which reinforce several of the *t*-test results reported earlier (see the Appendix A for a list of all "check all that apply" variables assessed using correlational analyses). The number of fatigue mitigation practices applicable to light vehicles had a significant inverse association with CPMM and %Fleet, while the number of fatigue mitigation practices combined across all vehicle sizes was significantly related to %Fleet ($r = -0.33$, $p < 0.01$). A stronger mobile phone policy was also inversely related to %Fleet ($r = -0.25$, $p < 0.05$). Finally, field managers' performance on road safety was marginally related to CPMM ($r = -0.33$, $p = 0.051$), and significantly related to IPMM ($r = -0.39$, $p < 0.05$).

As described earlier, composite variables also were created to address Hypothesis 2 (that companies with stronger consequences for violations of policies on specific road safety issues will have better fleet safety outcomes). The results of significant one-way ANOVAs are presented in Table 8 (see the Appendix A for a list of all variables with more than two mutually exclusive categories assessed using ANOVAs). As the ANOVA results show, checking mobile phone records after collisions, particularly for all collisions, was related to significantly lower CPMM and %Fleet. In addition, using IVMS to review all collisions was

Table 8
Relationships between outcome measures and fleet safety practices – significant results for ANOVA pairwise comparison tests (Tukey correction).

Outcome	Practice/policy	*F*-value	M	*sd*	*n*	Comparisons significant at $p < 0.05$
CPMM	Mobile phone record checking	5.44**				1–3, 2–3
	1. Not checked		5.35	1.87	37	
	2. Checked for serious collisions only		4.88	2.16	26	
	3. Checked after all collisions		2.25	1.69	5	
%Fleet	Mobile phone record checking	3.32*				1–3
	1. Not checked		11.00	5.17	38	
	2. Checked for serious collisions only		9.79	4.92	26	
	3. Checked after all collisions		4.93	4.07	5	
%Fleet	IVMS review	4.97*				3–4
	1. IVMS not in fleet		11.06	4.99	29	
	2. Not reviewed		8.37	5.18	15	
	3. After serious collisions only		13.70	5.55	9	
	4. After all collisions		7.44	3.98	14	

Notes: M = mean; sd = standard deviation; n = number of companies.
***$p < 0.001$.
* $p < 0.05$.
** $p < 0.01$.

also significantly related to lower %Fleet, when compared to companies that only checked after serious collisions (Table 8).

3.2. Regression results

The results of the linear regression analyses are presented in Table 9, with a separate final model for each outcome. In the multivariable context, several of the key variables from the bivariate analyses were also significant. The factor in Model 1 (CPMM) with the largest beta value was related to checking mobile phone records following a collision. Compared to companies that do not check these records, checking after all collisions was related to CPMMs 3.45 points lower, after controlling for other variables in the model. Compared with checking after serious collisions only, checking mobile phone records after all collisions was associated with significantly lower CPMM ($\beta = -2.74$, $p < 0.01$; comparison not shown in table). There was no significant difference between not checking records and checking only after serious collisions. For each additional fatigue mitigation practice applied to light vehicles (companies could identify up to 10), CPMMs were 0.29 points lower. Counter-intuitive results were observed for high-risk drivers and fleet safety scorecards; providing remote driver training (online, CD, DVD) as a response to high-risk drivers and publishing a fleet safety scorecard were both related to significantly higher CPMMs.

The %Fleet regression findings (Model 2) echo the CPMM findings for FRM and mobile phone record checking. Specifically, checking mobile records after all collisions was significantly related to lower %Fleet compared to not checking. There were no significant differences between either of the other options. In addition, this model revealed that several IVMS practices may play a role in understanding differences in %Fleet. Compared to companies that did not have IVMS, those that had IVMS but did not review the data after collisions had lower %Fleet ($\beta = -3.02$, $p < 0.05$), while those that reviewed it after serious collisions only actually had a higher %Fleet ($\beta = 4.02$, $p < 0.05$). In fact, compared to reviewing IVMS after serious collisions only, all other practices were related to significantly lower %Fleet ($\beta = -7.04$,

Table 9
Regression results assessing collision/injury outcomes with safety practices.

Outcome	Practice/policy	*β*	SE	*t*-value
Model 1: CPMM	High-risk drivers receive remote training (ref = no)	1.31	0.44	2.99**
$R^2 = 0.42$	# fatigue mitigation practices (LV)	−0.29	0.13	−2.20*
	Fleet safety scorecard published (ref = no)	1.04	0.50	2.09*
	Mobile phone record checking (ref = not checked)			
	Checked for serious collisions only	−0.72	0.46	−1.56
	Checked after all collisions	−3.45	0.82	−4.20***
Model 2: %Fleet	# fatigue mitigation practices (LV)	−0.79	0.37	−2.08*
$R^2 = 0.31$	IVMS review (ref = no IVMS)			
	Not reviewed	−3.02	1.46	−2.07*
	After serious collisions only	4.02	1.83	2.19*
	After all collisions	−0.67	1.70	−0.40
	Mobile phone record checking (ref = not checked)			
	Checked for serious collisions only	−2.10	1.31	−1.60
	Checked after all collisions	−6.19	2.36	−2.62*
Model 3: IPMM	Any form of driver training for new hires using non-company vehicles (ref = no)	−0.14	0.07	−2.04*
$R^2 = 0.14$	Collision review includes severity determination (ref = no)	−0.16	0.07	−2.23*

Notes: β = parameter estimate; SE = standard error; LV = light vehicles.
* $p < 0.05$.
** $p < 0.01$.
*** $p < 0.001$.

$p < 0.01$, for having IVMS, but not reviewing; $\beta = -4.69$, $p < 0.05$, for reviewing after all collisions).

In the regression assessing IPMM (Model 3), only two significant predictors remained in the final model. Providing driver training for new employees who drive non-company vehicles was significantly associated with 0.14 points lower IPMM, and including determination of severity in the collision review process was related to 0.16 points lower IPMM. There was much less variance in IPMM overall, compared to CPMM and %Fleet, and this model only explained about 14% of it. This lack of variance in the outcome could partly explain why fewer factors were predictive of IPMM in the multivariable context.

4. Discussion

The main goals of this study were to assess the two key hypotheses of interest, and to explore relationships between company fleet safety practices/policies and CPMM, %Fleet, and IPMM. The first hypothesis implied that companies with more fleet safety practices would have better collision/injury metrics than those with fewer practices. This hypothesis was partially supported. The relationships between the sum of all practices (intended to represent overall road safety within the company) and the three outcomes of interest were in the expected direction, but were not statistically significant; however, the sum of fatigue mitigation practices was (Section 3.1.4). As the number of fatigue mitigation practices applied to light vehicles increased, CPMM, %Fleet, and IPMM all decreased. The sum of fatigue mitigation practices across all vehicle sizes was also inversely related to %Fleet at a statistically significant level.

The second hypothesis suggested that stronger consequences for violations of fleet safety policies would be related to better collision and injury metrics. Again, partial support was observed for this hypothesis, with some practices showing a significant relationship, while others did not. The most notable examples were related to practices that are followed when a collision occurs. Checking mobile phone records, particularly after all collisions, was related to significantly lower CPMM and %Fleet, and was a significant factor in both the bivariate and multivariable context (Tables 8 and 9). Reviewing IVMS information after all collisions was significantly related to lower %Fleet in the bivariate context, compared to doing a review after serious collisions only (Table 8). In the regression model, companies that simply reported having IVMS, even without reviewing the data (Table 9), and somewhat counter-intuitively, companies that reviewed it only after serious collisions actually had the highest %Fleet compared to those in the other categories (Table 8). This counter-intuitive result implies that using IVMS data as a reaction to serious collisions only is not consistent with this technology's intended use: continuous analysis of all IVMS data combined with timely supervisory coaching to correct risky driving behaviors before a collision occurs. Other studies have demonstrated that in-vehicle driver feedback combined with coaching significantly reduced risky driving behaviors among those who drove for work (Bell et al., 2017, Hickman and Hanowski, 2011). Although not all the relationships in the NETS data were in the expected direction, the overall findings pertaining to IVMS suggest it may play an important role in distinguishing between higher and lower performing fleets, but future study of this factor is required to more fully understand it.

This study also explored how different practices and policies affect road safety metrics. Given that the three different outcomes are related but unique measures of road safety, it was not surprising to observe differences in which practices/policies were significantly related to each outcome, and in the level of significance for practices related to multiple outcomes. CPMM is a different safety metric (using exposure) than is %Fleet, which is different still from IPMM (again accounting for exposure). All these metrics, however, adjust for company differences in miles driven or numbers of vehicles. Given that differences exist, one potential approach for interpretation of these results is to look for common themes that play a role in more than one outcome metric, and particularly for those that were significant in the multivariable context. Indeed, several such themes emerged: duration of road safety program, time since program revision, company leaders' involvement (i.e., corporate executive team who champion road safety and field managers' performance), driver training, response to collisions, the fleet safety scorecard, and fatigue risk management.

Time since revising the company's road safety program was significantly related to each of the three metrics (Tables 4–6). Results were mixed, however, and several interpretations are possible. It may be that companies recognize a problem and actively work to improve their program, with the intention of lowering collisions and injuries in the future. Other companies may view their positive metrics as reason to maintain their current fleet safety practices without the need to make any changes. Still others with positive metrics may continue to monitor small changes in their metrics with the goal of continuous improvement in their management practices. Finally, it is also possible that for the question asking when the last significant revision or addition was made to their road safety program, companies did not all interpret "significant" in the same way.

Positive associations between safety outcomes and company leaders' road safety championing and performance were seen at two levels within NETS member companies. First, in the bivariate analysis, there was a highly significant relationship ($p < 0.001$) between IPMM and championing of road safety by the corporate executive team (Table 6). Second, in the correlation analysis, field managers' level of performance on road safety was significantly associated with lower IPMMs and marginally related to lower CPMMs (Table 7). These results are consistent with other research that found commitment to road safety at top levels of organizations to be associated with safer driving behaviors (Banks, 2008) and more positive perceptions of driving safety culture (Arboleda et al., 2003, Wills et al., 2005, Wills et al., 2006). Another study reported significant correlations between management commitment and a range of self-reported driver behaviors grouped under four main themes: driver errors, violations of traffic laws or safe driving practices, distracted/fatigued/impaired driving, and adherence to pre-trip maintenance procedures (Wills et al., 2006). Further, the results of this study align with findings from the broader OSH literature that demonstrate the importance of the commitment of company leaders to the success of OSH initiatives (Loeppke et al., 2015, Sorensen et al., 2013, 2018). These previous findings suggest that commitment to road safety at the management level has an important influence on drivers' perceptions about safety and self-reported driving behaviors, while the analysis of NETS benchmarking data reported here adds information about the relationship between corporate executives' championing of road safety and positive fleet safety outcomes at the company level.

A number of program elements related to driver training were significantly related to all three outcomes in both the bivariate and multivariable contexts, but not always in the expected direction. The bivariate results showed that although providing training to all drivers was significantly associated with lower %Fleet and lower IPMM (Tables 5 and 6), applying more intensive training approaches to high-risk drivers was also significantly associated with better outcomes (for example, behind-the-wheel and classroom training for high-risk drivers were associated with lower IPMM in the bivariate analysis [Table 6]). However, not all training results were intuitive; remote training for high-risk drivers was significantly associated with higher CPMM in both the bivariate and multivariable analyses (Tables 4 and 9). It is possible that this level of training was not adequate to remediate high-risk driving or that drivers did not take this type of training seriously. Moreover, training is considered to be a lower level of hazard control, compared to those that mitigate a hazard or eliminate it altogether (such as restricting night driving), or mitigate it through engineering changes (such as purchasing vehicles with features such as automatic emergency braking) (Bird and Germain, 1996).

The generally positive associations between driver training and the three study outcomes are inconsistent with a systematic review of post-license driver training, which found no evidence of its effectiveness in reducing crashes or injuries (Ker et al., 2005). However, few of these studies were conducted in an occupational setting, and some of them were low-intensity interventions such as correspondence courses. Studies of driver training conducted in occupational settings have shown more positive results (Arboleda et al., 2003, Gregersen et al., 1996, Salminen, 2008, Wills et al., 2006). Because of the occupational settings, the training results from these four studies are more directly comparable to the results reported here for NETS member companies than are results from assessments of post-license or remedial training in the general population.

How a company responds to a collision was one of the most important themes that emerged, and it was noted in several different forms. Determining the collision severity (including the extent of damage, costs, and injuries) was significantly related to each of the outcomes, including the IPMM regression model (Tables 4–6, and 9). As discussed, checking mobile phone records following a collision was also a key predictor of both collision metrics, and in both the bivariate and multivariable contexts (Tables 8 and 9). Reviewing IVMS information after all collisions was also significantly associated with lower %Fleet (Table 8). Collectively, these factors suggest that a serious and complete response to a collision is related to lower CPMM and %Fleet, and potentially to fewer injuries.

Results related to data collection and use of a fleet safety scorecard were mixed. Four scorecard-related elements were significantly associated with lower CPMM, one with lower %Fleet, and six with lower IPMM. These results support the importance of ongoing data collection and reporting, and they imply a commitment to information-sharing throughout an organization, all of which are viewed as best practices (ANSI/ASSP, 2017a, Bidasca and Townsend, 2014, Mitchell et al., 2012).

One element related to the fleet safety scorecard found to be significantly associated with lower CPMM was publishing the scorecard to drivers (Table 4). This supports the value of communicating safety-related information at all levels of an organization, not just to upper management. This finding is consistent with research that demonstrated that higher quality of communication between the driver and supervisor was associated with safer driving behaviors (Banks, 2008, Newnam et al., 2012). In another study, having road safety rules and communicating them throughout the organization were strongly associated with positive organizational safety climate (Wills et al., 2005, Wills et al., 2006).

A few counter-intuitive results related to data collection and the scorecard were also observed. For example, reporting preventable and non-preventable collisions on the scorecard was significantly associated with higher CPMM, and not checking driving records was significantly associated with lower IPMM. Companies that are in the process of improving their procedures for data collection and review may have less favorable metrics in some cases because they are identifying more incidents and collisions. Because the results regarding scorecards are mixed, conclusions should be drawn with caution. Further examination of the relationship between scorecards and fleet safety outcomes would require analysis across multiple data years combined with assessments of changes in procedures for data collection and review. Such assessments would necessarily involve methods beyond the NETS questionnaire, including in-depth program audits and key informant interviews.

The application of FRM to drivers of light, medium, and heavy vehicles was the final theme that was common among all three metrics, and in both the bivariate context and regression models, with particularly strong findings related to lower IPMMs. For light and heavy vehicles, providing fatigue training for new hires and providing medical screenings for fatigue were both significantly associated with lower IPMMs. It should be noted, however, that these practices have only recently begun to be assessed by NETS and were implemented by a smaller number of companies than many of the other practices. It could be that the most progressive companies (in terms of road safety) are the early adopters of FRM for light-vehicle drivers.

Since the 1930s, heavy vehicles and their drivers in the U.S. have been covered by hours-of-service regulations that set maximum driving and duty hours, for the purpose of managing driver fatigue. Based on the findings presented here, it appears that application of non-regulatory fatigue risk management to all vehicle sizes is associated with positive fleet safety outcomes, particularly lower IPMMs. Consistent with these findings, a voluntary consensus standard based on best practice recommends FRM for all drivers (ANSI/ASSP, 2017a), and road safety guidance used by the oil and gas industry provides FRM recommendations that do not distinguish between vehicle sizes and regulatory environments (International Association of Oil & Gas Producers, 2016). Further, medical experts have noted the one-dimensional nature of the hours-of-service regulations that cover heavy-vehicle drivers, calling for a more flexible, comprehensive approach to FRM (Lerman et al., 2012). This more comprehensive approach would consider a variety of strategies, including: intervening within the "chain of responsibility" that includes shippers, dispatchers, and receivers; the use of occupational physicians to provide expertise in scheduling and medical screening; taking into account the relationships between shift work, long work hours, and fatigue; and training workers to help them manage fatigue and improve sleep both on and off the job (Gander et al., 2011, Lerman et al., 2012). Some of these – medical screenings, FRM training, and restrictions on night driving (a scheduling intervention) – were identified in the NETS benchmarking data as being significantly associated with better fleet safety outcomes.

Other research has assessed the effectiveness of fatigue training for individuals who drive for work. A study of truck drivers found that fatigue training was associated with statistically significant improvements in drivers' perceptions of organizational safety climate post-training (Arboleda et al., 2003). Another study assessed the effectiveness of workplace fatigue training for both heavy- and light-vehicle drivers in a petrochemical company (Gander et al., 2005). In that study, heavy-vehicle drivers showed statistically significant improvements in knowledge based on a post-training quiz, and follow-up questionnaires two years post-training showed good knowledge retention. Two years post-training, 47% of respondents reported they had changed their fatigue management strategies at work, and 49% reported changing them at home. Similar results were reported for light-vehicle drivers in the same company, who received a version of the same fatigue training adapted for their workplace driving environment. Gander et al. (2005) was the only study of the effectiveness of FRM in light-vehicle fleets found in the literature. The positive findings from the NETS data regarding FRM for light-vehicle drivers suggest a need for additional intervention research to strengthen the evidence for its effectiveness.

4.1. Strengths and limitations

This study has a number of notable strengths. For the first time, it brings together data on fleet safety outcomes and programs for a large number of company fleets of all types, which accounted for more than

5.4 billion U.S. VMT in 2016. Further, the companies that participated responded to a detailed questionnaire about fleet safety programs and practices, making it possible to identify statistically significant relationships between program elements and road safety performance. Data were collected using a standard protocol and definitions, with participating companies receiving technical assistance as necessary. Collision and injury rates were calculated using VMT, which is a more precise measure of exposure than number of workers employed, the most commonly used measure of exposure in the occupational safety literature. These analyses also used three different outcome metrics to assess fleet safety practices, strengthening the validity of the findings, especially those that were common to all three.

Several limitations must also be acknowledged. The cross-sectional nature of the study means that observed relationships between variables do not denote causality. In addition, a minority of companies allowed personal use of company-provided vehicles by the employee and/or spouse, where mileage and crashes could not be disaggregated from employee business use. Further, data on fleet safety practices were self-reported, and respondents were only asked about the presence or absence of policies. A more in-depth research design incorporating audits and key informant interviews would be needed to ascertain the quality of implementation of the fleet safety policies addressed in the NETS questionnaire, and the extent to which companies may be changing their policies based on the NETS benchmarking analysis.

Certain fleet safety policies and practices tended to co-occur, but it was not possible to determine the individual contribution of each of these. Because the company was the unit of analysis, the number of observations available for multivariable analysis was relatively small. Although CPMM, IPMM, and %Fleet were rates (which adjusted for differences in either exposure or number of vehicles), statistical analyses did not include additional exposure-related control variables. Additionally, a large number of bivariate statistical tests were conducted, which could have resulted in some significant results due only to chance. However, a goal of this study was to explore how all practices affected these outcomes, which required the completion of numerous tests, and the regression analyses accounted for this issue.

Although quality checks were conducted after data from all the companies were compiled, it is possible that individual companies may not have adhered strictly to case definitions when submitting data. In addition, the data were limited to U.S. vehicle use for the participating companies, so the findings cannot be generalized to other countries. Additionally, for several reasons, the results are not necessarily generalizable to all U.S. companies that operate motor vehicles: (1) most benchmark participants were large companies, which may have more resources to devote to road safety management than smaller companies and thus have better data collection practices in place; (2) NETS is a membership organization comprising companies that already tend to have good road safety practices; and (3) participation in the benchmark was voluntary, and the distribution of companies by industry does not reflect the distribution of industry in the U.S. economy. Further, because some practices were nearly universally followed across NETS member companies, for example, adoption of a mobile phone policy, no significant results were observed, but these remain key practices for companies that lack such a policy to consider.

Another set of limitations pertains to the level at which data were collected. Collection of data at the company level only did not allow for assessment of differences between organizational units within the same company, which might have provided useful insights about how varying levels of policy implementation within these units were related to the outcome measures. In addition, using the company as the unit of analysis does not address the underlying organizational, interpersonal, and individual factors at lower levels of these companies, which have been shown to be associated with positive road safety climate (Wills et al., 2005, 2006) and safer driving behaviors (Banks, 2008, Newnam et al., 2012). Research to assess drivers', supervisors', and safety managers' road safety knowledge, attitudes, and behaviors, either as a case study in a single NETS member company or across several companies, may be a useful adjunct to the company-level results reported here.

Finally, analyses were limited by the questions included in the NETS questionnaire. Of note, the outcome measures are limited to lagging indicators: collision and injury rates. Further, because NETS as an organization is focused on road safety management, not other aspects of OSH management, questions that accompanied submission of benchmarking data did not address the integration of road safety management within the larger OSH management system. Because these concepts were not measured by the NETS questionnaire, the extent to which features of the larger OSH management system may have contributed to fleet safety outcomes is unknown. This is a topic that may be considered for inclusion in future questionnaires.

4.2. Conclusion

These analyses identified several practices and policies that could serve as a guide for companies aspiring to improve road safety for vehicles operated on their behalf, and thereby reduce collisions, associated costs, and employee injuries: duration of the road safety program, time since program revision, company leaders' safety commitment and performance, driver training, response to collisions, the fleet safety scorecard, and fatigue risk management. A number of practices were common across the three metrics (CPMM, %Fleet, and IPMM), and even after controlling for other factors in the regression models. Companies looking for promising approaches should focus on the fleet safety practices identified through this study, as well as the practices they feel are the most adoptable/changeable in their environment.

The findings and conclusions in this report are those of the authors and do not necessarily represent the views of the National Institute for Occupational Safety and Health, Centers for Disease Control and Prevention.

Mention of any company or product does not constitute endorsement by the National Institute for Occupational Safety and Health, Centers for Disease Control and Prevention. In addition, citations to websites external to NIOSH do not constitute NIOSH endorsement of the sponsoring organizations or their programs or products. Furthermore, NIOSH is not responsible for the content of these websites. All web addresses referenced in this document were accessible as of the publication date.

Funding

This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

Appendix A

See Table A1.

Table A1
Topics and response choices used to create variables.

Topic: Response choices
Years road safety program in place: In (re)development; 1; 2; 3… 9; 10+
Last time company made significant revision: Currently; 2–5 years ago; > 5 years ago
Extent of revisions: Overall road safety program revised or new; Revisions to specific practices or policies
Specific areas of revisions*: Commentary drive process; High-risk drivers; Collision reviews; Road safety metrics/scorecard; Driver training; In-vehicle monitoring systems (IVMS); Mobile phone use; Fatigue programs; Training for managers related to road safety; Other
Which drivers receive driver training*: New hires company vehicles; New hires non-company vehicles; High-risk drivers; Drivers whose supervisors recommend training; Periodic training all employees company vehicles; Family members of employees; All employees; No driver training programs in place
Identify high-risk drivers: Yes; No
Sources of data used to classify high risk*: IVMS; Driver audits, observations, or commentary drives; Hotline feedback; Managers' recommendations; Driving records from company, insurance or public records; Other
Data classification system*: Point System; Periodic System; Statistically validated predictive models; Specific incident can trigger high-risk classification; Other
Response(s) to high-risk classification*: Currently, little or no follow-up occurs; Remote driver training (online, CD, DVD); Classroom training; Behind-the-wheel driver training; Commentary drives; Collision reviews; Special coaching or counseling sessions; Disciplinary action, possibly termination or suspension; Collision-cost sharing or other monetary penalty; Vehicle selection limitations; IVMS placed in drivers' vehicle; Revocation of driving privileges (for company vehicles); Other
Conduct commentary drives: Yes; No
In which circumstances*: For new hires; For high-risk drivers; Follow-up when collisions occur; As part of behind-the-wheel training; Periodic commentary drives conducted with tenured drivers
Review collisions: Yes; No
Components of collision review process*: Review between driver and immediate manager; Special team/board; Determination of severity; Determination of preventability/non-preventability; Report issued to senior management for serious collisions; Corrective actions developed; Follow-up to ensure corrective actions implemented; Lessons learned are shared throughout organization; Other
Fatigue program**: Did not report metrics specific to light/medium/heavy vehicles; Addressing fatigue in less than 80% of light fleet; Company standards established for driving/rest hours; Required fatigue training for new hires; Periodic training for all drivers; Optional training; Periodic evaluations; Medical screenings for fatigue; Driver surveys on fatigue; One-on-one sessions with drivers to manage sleep/fatigue; Empower workers to report fatigue; Restrictions on night driving; Partner driving (asked for medium and heavy vehicles only)
Use of IVMS: Yes; No
If NO, plan to use IVMS in future: Yes; No; Undecided
Extent of IVMS use: Piloting IVMS devices; Past pilot stage but used in < 80% vehicles; Used in ≥80% of vehicles
IVMS features for majority of vehicles*: Device that beeps or flashes; Device that records specific trigger events; Camera(s) recording outside; Camera(s) recording driver/inside; Camera(s) that save when any trigger occurs; Metrics/recordings available via manual online retrieval; Non-safety functions such as route planning; Uncertain
Who receives IVMS data*: Driver; Drivers' immediate managers; Safety staff; Fleet staff; Summaries to upper management
IVMS management*: Not actively managed; Drivers reviewed own metrics; Managers reviewed metrics with group; Managers reviewed metrics with individual drivers
IVMS data reviewed after collision: Yes, for all collisions; Yes, for serious collisions only; No
Publish road safety scorecard: Yes; No
Data points included on scorecard*: CPMM, or similar rate; Collisions per 100 vehicles, or similar; Collisions per hours driven or worked; % of fleet involved in collisions; Collision-related injuries or fatalities; Collision-related lost work days; Severity; Preventable/non-preventable collisions; Specific types of collisions; Near-misses; Trigger events from IVMS; Collisions on company time vs. personal time; Commentary drive completions; Driver training completions; Collision review completions; Individual driver action plan development/completion; Costs of collisions; % of fleet considered high risk
Publish to which groups*: Members of corporate executive group; Senior management; Field/middle management; Leaders of safety, health, environment group; Leaders of fleet management; Drivers
Periodicity: Monthly; Quarterly; Annually
Make an effort to track near-misses: Yes; No
Written mobile phone policy: Yes, formal, written companywide policy; Formal written policy at discretion of countries/businesses; Guidelines/recommendations only; Working on developing formal policy; Currently no plans to develop policy
Which best describes policy: Banned/restricted only texting/typing; Allowed hands-free technology; Banned any phone while driving
Response if driver involved in a collision while using phone*: No special action is taken; Issue warning; Disciplinary action; Termination; Conduct commentary drive; Assign training; Classify driver high risk
Use technology to restrict phone use: No; No, but considering it; Yes, limited basis; Yes, used in 80% or more of vehicles
Check phone records after collision: Yes, for all collisions; Yes, serious collisions only; No
One or more corporate executive champion(s): Yes; No
Rate executive team's support: 1–5
Field managers assigned specific responsibilities: Yes; No
Rate field managers' performance: 1–5
Required on all new light vehicles in U.S.*: Seat belts; Front air bags; Side air bags; Other air bags; Anti-lock braking system; Electronic stability control; Back-up camera/sensor; Blind spot sensor/side camera; Tire pressure monitoring system; Daytime running lights; Navigation systems; Lane-departure warning systems; Forward collision warning; Emergency brake assistance; Adaptive speed for cruise control; Adaptive headlights; DUI ignition lock; In-vehicle monitoring system; Rollover protection systems; Require maximal crash ratings
Frequency motor vehicle records were checked for drivers of co. vehicles: Only at hire; Annually; Two times per year; Quarterly; Continuously (automatically notified of any MVR changes); Do not routinely check

Notes:

* Respondents directed to choose all that apply.

** First two responses exclusive, all other responses: choose all that apply; asked separately for light, medium, heavy, and site vehicles. For all items with “chose all that apply” options, additional variables were also created that represented the total of items chosen.

References

ANSI/ASSP, 2017a. ANSI/ASSP Z15.1-2017, Safe Practices for Motor Vehicle Operations. American National Standards Institute, New York.

ANSI/ASSP, 2017b. ANSI/ASSP Z10-2012 (R2017), Occupational Health and Safety Management Systems. American National Standards Institute, New York.

Arboleda, A., Morrow, P.C., Crum, M.R., Shelley II, M.C., 2003. Management practices as antecedents of safety culture within the trucking industry: similarities and differences by hierarchical level. J. Saf. Res. 34, 189–197. https://doi.org/10.1016/S0022-4375(02)00071-3.

Banks, T.D., 2008. An investigation into how work-related road safety can be enhanced. PhD Thesis. Centre for Accident Research and Road Safety – Queensland (CARRS-Q), Queensland Institute of Technology, Brisbane, Australia. https://eprints.qut.edu.au/29683/2/Tamara_Banks_Thesis.pdf.

Bell, J.L., Taylor, M.A., Chen, G.-X., Kirk, R.D., Leatherman, E.R., 2017. Evaluation of an in-vehicle monitoring system (IVMS) to reduce risky driving behaviors in commercial drivers: comparison of in-cab warning lights and supervisory coaching with videos of driving behavior. J. Saf. Res. 60, 125–136. https://doi.org/10.1016/j.jsr.2016.12.008.

Bidasca, L., Townsend, E., 2014. The Business Case for Managing Road Risk at Work. European Transport Safety Council, Brussels.

Bird Jr., F.E., Germain, G.L., 1996. Practical Loss Control Leadership, revised ed. Det Norske Veritas, Loganville, GA.

Bureau of Labor Statistics, 2012. Occupational Injury and Illness Classification Manual, Version 2.01. Bureau of Labor Statistics, Washington, DC. https://www.bls.gov/iif/oiics_manual_2010.pdf.

Bureau of Labor Statistics, 2016. Table R70. Number and Percent Distribution of Nonfatal Occupational Injuries and Illnesses Involving Days away from Work by Event or Exposure Leading to Injury or Illness and Number of Days away from Work, and Median Number of Days away from Work, Private Industry, 2015. Bureau of Labor Statistics, Washington, DC.

Bureau of Labor Statistics, 2017a. Table A-2. Fatal Occupational Injuries Resulting from Transportation Incidents and Homicides, all United States, 2003-2015. Bureau of Labor Statistics, Washington, DC.

Bureau of Labor Statistics, 2017. Table A-6. Fatal Occupational Injuries Resulting from Transportation Incidents and Homicides by Occupation, all United States, 2003-2015. Bureau of Labor Statistics, Washington, DC.

Callen, A., Wilson, S., 2015. Review of Successful Occupational Safety and Health Benchmarking Initiatives. European Agency for Safety and Health at Work, Bilbao, Spain. https://osha.europa.eu/en/tools-and-publications/publications/report-eu-osha-review-successful-occupational-safety-and-health.

Campbell, K.L., 1991. Fatal accident involvement rates by driver age for large trucks. Accid. Anal. Prev. 23 (4), 287–295. https://doi.org/10.1016/j.jsr.2016.12.008.

Cantor, D.E., 2014. A Firm Size and Safety Performance Profile of the US Motor Carrier Industry. Midwest Transportation Center, Iowa State University, Ames, IA.

CDC, 2003. Ambulance crash-related injuries among emergency medical services workers – United States, 1991–2002. MMWR 52 (8), 154–156.

Chen, G.X., Amandus, H.E., Wu, N., 2014. Occupational fatalities among driver/sales workers and truck drivers in the United States, 2003–2008. Am. J. Ind. Med. 57 (7), 800–809. https://doi.org/10.1002/ajim.22320.

Darby, P., Murray, W., Raeside, R., 2009. Applying online fleet driver assessment to help identify, target and reduce occupational road safety risks. Saf. Sci. 47 (3), 436–442. https://doi.org/10.1016/j.ssci.2008.05.004.

Darby, P., Quddu, M., Murray, W., Raeside, R., Ison, S., 2011. Evaluation of fleet road safety interventions. 90th Annual Meeting of the Transportation Research Board, Washington, DC.

Driscoll, T., Marsh, S., McNoe, B., Langley, J., Stout, N., Feyer, A.-M., Williamson, A., 2005. Comparison of fatalities from work related motor vehicle traffic incidents in Australia, New Zealand, and the United States. Injury Prevent. 11 (5), 294–299. https://doi.org/10.1136/ip.2004.008094.

European Transport Safety Council, 2012. Preventing Road Accidents and Injuries for the Safety of Employees: Project Handbook. European Transport Safety Council, Brussels.

Federal Motor Carrier Safety Administration, 2017. Large Truck and Bus Crash Facts 2015. Federal Motor Carrier Safety Administration, Washington, DC.

Fowles, R., Loeb, P.D., Clarke, W., 2013. The cell phone effect on truck accidents: a specification error approach. Transp. Res. Part E: Logist. Transp. Rev. 50C, 18–28. https://doi.org/10.1016/j.tre.2012.10.002.

Gander, P., Hartley, L., Powell, D., Cabon, P., Hitchcock, E., Mills, A., Popkin, S., 2011. Fatigue risk management: organizational factors at the regulatory and industry/company level. Accid. Anal. Prev. 43 (2), 573–590. https://doi.org/10.1016/j.aap.2009.11.007.

Gander, P.H., Marshall, N.S., Bolger, W., Girling, I., 2005. An evaluation of driver training as a fatigue countermeasure. Transp. Res. Part F: Traff. Psychol. Behav. 8 (1), 47–58. https://doi.org/10.1016/j.trf.2005.01.001.

Gregersen, N.P., Brehmer, B., Morén, B., 1996. Road safety improvement in large companies. An experimental comparison of different measures. Accid. Anal. Prev. 28 (3), 297–306. https://doi.org/10.1016/0001-4575(95)00060-7.

Guest, M., Boggess, M.M., Duke, J.M., 2014. Age related annual crash incidence rate ratios in professional drivers of heavy goods vehicles. Transp. Res. Part A: Pol. Pract. 65, 1–8. https://doi.org/10.1016/j.tra.2014.04.003.

Hickman, J.S., Hanowski, R.J., 2011. Use of a video monitoring approach to reduce at-risk driving behaviors in commercial vehicle operations. Transp. Res. Part F: Traff. Psychol. Behav. 14 (3), 189–198. https://doi.org/10.1016/j.trf.2010.11.010.

Hymel, P.A., Loeppke, R.R., Baase, C.M., Burton, W.N., Hartenbaum, N.P., Hudson, T.W., McLellan, R.K., Mueller, K.L., Roberts, M.A., Yarborough, C.M., Konicki, D.L., Larson, P.W., 2011. Workplace health protection and promotion: a new pathway for a healthier—and safer—workforce. J. Occup. Environ. Med. 53, 695–702. https://doi.org/10.1097/JOM.0b013e31822005d0.

International Association of Oil & Gas Producers, 2016. Land Transportation Safety Recommended Practice (OGP 365), version 3.0 (November 2016). International Association of Oil & Gas Producers, Land Transportation Safety Subcommittee, London.

International Organization for Standardization, 2012. ISO 39001:2012, Road Traffic Safety (RTS) management systems - Requirements with Guidance for Use. International Organization for Standardization, Geneva, Switzerland.

Ker, K., Roberts, I., Collier, T., Beyer, F., Bunn, F., Frost, C., 2005. Post-licence driver education for the prevention of road traffic crashes: a systematic review of randomised controlled trials. Accid. Anal. Prev. 37 (2), 305–313. https://doi.org/10.1016/j.aap.2004.09.004.

Lerman, S.E., Eskin, E., Flower, D.J., George, E.C., Gerson, B.M., Hartenbaum, N., Hursh, S.R., Moore-Ede, M., 2012. Fatigue risk management in the workplace. J. Occup. Environ. Med. 54 (2), 231–258. https://doi.org/10.1097/JOM.0b013e318247a3b0.

Liberty Mutual Insurance Company, 2018. 2018 Workplace Safety Index: The top 10 causes of Disabling Injuries. Liberty Mutual Insurance Company, Boston, MA. https://viewpoint.libertymutualgroup.com/article/2018-workplace-safety-index/.

Loeppke, R.R., Hohn, T., Baase, C., Bunn, W.B., Burton, W.N., Eisenberg, B.S., Ennis, T., Fabius, R., Hawkins, R.J., Hudson, T.W., Hymel, P.A., Konicki, D., Larson, P., McLellan, R.K., Roberts, M.A., Usrey, C., Wallace, J.A., Yarborough, C.M., Siuba, J., 2015. Integrating health and safety in the workplace: How closely aligning health and safety strategies can yield measurable benefits. J. Occup. Environ. Med. 57 (5), 585–597. https://doi.org/10.1097/JOM.0000000000000467.

Lyman, S., Braver, E., 2003. Occupant deaths in large truck crashes in the United States: 25 years of experience. Accid. Anal. Prev. 35 (5), 731–739. https://doi.org/10.1016/S0001-4575(02)00053-2.

Menachof, D., Wassenberg, O., 2000. The application of benchmarking techniques by road transport companies in the United Kingdom and the Netherlands. Transp. J. 40 (2), 40–56.

Mitchell, R., Driscoll, T., Healey, S., 2004. Work-related road fatalities in Australia. Accid. Anal. Prev. 36 (5), 851–860. https://doi.org/10.1016/j.aap.2003.06.002.

Mitchell, R., Friswell, R., Mooren, L., 2012. Initial development of a practical safety audit tool to assess fleet safety management practices. Accid. Anal. Prev. 47, 102–118. https://doi.org/10.1016/j.aap.2012.01.021.

Mooren, L., Grzebieta, R., Williamson, A., Olivier, J., Friswell, R., 2014a. Safety management for heavy vehicle transport: a review of the literature. Saf. Sci. 62, 79–89. https://doi.org/10.1016/j.ssci.2013.08.001.

Mooren, L., Williamson, A., Friswell, R., Olivier, J., Grzebieta, R., Magableh, F., 2014b. What are the differences in management characteristics of heavy vehicle operators with high insurance claims versus low insurance claims? Saf. Sci. 70, 327–338. https://doi.org/10.1016/j.ssci.2014.07.007.

Mooren, L., 2015. NRSPP Fleet Safety Benchmarking Project: Literature Review. ARRB Group and University of New South Wales, Sydney. https://s3-ap-southeast-2.amazonaws.com/cdn-nrspp/wp-content/uploads/sites/4/2017/03/30121607/NRSPP-Lit-Review-National-Benchmark-Project-Final-Report-2015-061.pdf.

Morris, C.C., 2015. Motor Vehicle Occupant Fatality Risk based on Person-Time Exposed: Age, Sex, and Period of Week. U.S. Department of Transportation, Washington, DC.

Murray, W., White, J., Ison, S., 2012. Work-related road safety: a case study of Roche Australia. Saf. Sci. 50 (1), 129–137. https://doi.org/10.1016/j.ssci.2011.07.012.

National Transport Commission (Australia), Accident Compensation Corporation (New Zealand), 2013. Occupational Work Related Road Safety Guide: A Guide to Applying Road Safety within a Workplace. NTC and ACC, Melbourne and Wellington.

Network of Employers for Traffic Safety, 2014. NETS Comprehensive Guide To Road Safety. Network of Employers for Traffic Safety, Vienna, VA.

Network of Employers for Traffic Safety, 2015. Cost of Motor Vehicle Crashes to Employers – 2015. NETS, Vienna, VA.

Newnam, S., Lewis, I., Watson, B., 2012. Occupational driver safety: conceptualising a leadership-based intervention to improve safe driving performance. Accid. Anal. Prev. 45, 29–38. https://doi.org/10.1016/j.aap.2011.11.003.

Occupational Safety and Health Administration, 2017. OSHA Injury and Illness Recordkeeping and Reporting Requirements. OSHA, Washington, DC.

Ore, T., Fosbroke, D.E., 1997. Motor vehicle fatalities in the United States construction industry. Accid. Anal. Prev. 29 (5), 613–626. https://doi.org/10.1016/S0001-4575(97)00013-4.

Ozkaya, E., Keskinocak, P., Joseph, V.R., Weight, R., 2010. Estimating and benchmarking less-than-truckload market rates. Transp. Res. Part E: Log. Transp. Rev. 46 (5), 667–682. https://doi.org/10.1016/S0001-4575(97)00013-4.

Pratt, S.G., Bell, J.L., 2019. Analytical observational study of nonfatal motor vehicle collisions and incidents in a light-vehicle sales and service fleet. Accid. Anal. Prev. 129, 126–135.

Pratt, S.G., Rodríguez-Acosta, R., 2015. Preventing Work-Related Motor Vehicle Crashes (NIOSH Pub. No. 2015-111). NIOSH, Morgantown, WV.

Pratt, S.G., Rodríguez-Acosta, R.L., 2013. Occupational highway transportation deaths among workers aged ≥55 years — United States, 2003–2010. MMWR 62 (33), 653–657.

Retzer, K.D., Hill, R.D., Pratt, S.G., 2013. Motor vehicle fatalities among oil and gas extraction workers. Accid. Anal. Prev. 51, 168–174. https://doi.org/10.1016/j.aap.2012.11.005.

Salminen, S., 2008. Two interventions for the prevention of work-related road accidents. Saf. Sci. 46, 545–550. https://doi.org/10.1016/j.ssci.2007.05.007.

Sorensen, Glorian, McLellan, Deborah, Dennerlein, Jack T., Pronk, Nicolaas P., Allen, Jennifer D., Boden, Leslie I., Okechukwu, Cassandra A., Hashimoto, Dean, Stoddard, Anne, Wagner, Gregory R., 2013. Integration of health protection and health

promotion: rationale, indicators, and metrics. J. Occup. Environ. Med. 55, S12–S18. https://insights.ovid.com/crossref?an=00043764-201312001-00003https://doi.org/10.1097/JOM.0000000000000032.
Sorensen, G., Sparer, E., Williams, J.A.R., Gundersen, D., Boden, L.I., Dennerlein, J.T., Hashimoto, D., Katz, J.N., McLellan, D.L., Okechukwu, C.A., Pronk, N.P., Revette, A., Wagner, G.R., 2018. Measuring best practices for workplace safety, health, and well-being: The Workplace Integrated Safety and Health Assessment. J. Occup. Environ. Med. 60 (5), 430–439. https://doi.org/10.1097/JOM.0000000000001286.
Tiesman, H.M., Swedler, D.I., Konda, S., Pollack, K.M., 2013. Fatal occupational injuries among U.S. law enforcement officers: a comparison of national surveillance systems. Am. J. Ind. Med. 56 6, 693–700. https://doi.org/10.1002/ajim.22182.
Torrey IV, W.F., Murray, D.C., 2015. An Analysis of the Operational Costs of Trucking: 2015 Update. American Transportation Research Institute, Arlington, VA.
Wachter, J.D., Yorio, P.L., 2014. A system of safety management practices and worker engagement for reducing and preventing accidents: an empirical and theoretical investigation. Accid. Anal. Prev. 68, 117–130. https://doi.org/10.1016/j.aap.2013.07.029.
Wallington, D., Murray, W., Darby, P., Raeside, R., Ison, S., 2014. Work-related road safety: case study of British Telecommunications (BT). Transp. Policy 32, 194–202. https://doi.org/10.1016/j.tranpol.2014.01.002.
Warmerdam, A., Newnam, S., Sheppard, D., Griffin, M., Stevenson, M., 2017. Workplace road safety risk management: an investigation into Australian practices. Accid. Anal. Prev. 98, 64–73. https://doi.org/10.1016/j.aap.2016.09.014.
Wills, A.R., Biggs, H.C., Watson, B., 2005. Analysis of a safety climate measure for occupational vehicle drivers and implications for safer workplaces. Austr. J. Rehabil. Counsell. 11, 8–21. https://doi.org/10.1017/S1323892200000132.
Wills, A.R., Watson, B., Biggs, H.C., 2006. Comparing safety climate factors as predictors of work-related driving behavior. J. Saf. Res. 37 (4), 375–383. https://doi.org/10.1016/j.jsr.2006.05.008.
Woodrooffe, J., Glaeser, K.-P., Nordengen, P., 2010. Truck productivity, efficiency, energy use, and carbon dioxide output: benchmarking of international performance. Transp. Res. Rec. 2162, 63–72. https://doi.org/10.3141/2162-08.