International Transport Forum

On-Board Safety Systems: Enablement of Management and Logistics

15

Discussion Paper 2017 • 15

John Woodrooffe

Woodrooffe Dynamics LLC,
Ann Arbor, Michigan

OECD

On-Board Safety Systems

Enablement of Management and Logistics

Discussion Paper 2017-15

Prepared for the Roundtable on
Commercial Vehicle On-Board Safety Systems
January 5 – 6, 2017
Washington DC

John Woodrooffe
Woodrooffe Dynamics LLC, Ann Arbor MI, USA
www.woodrooffe.com

August 2017

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International Transport Forum
2 rue André Pascal
F-75775 Paris Cedex 16
contact@itf-oecd.org
www.itf-oecd.org

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Acknowledgements

The author is grateful for the contributions from Daniel Blower University of Michigan Transportation Research and Sharon Newnam Monash University Accident Research Centre.

Abstract

On-board commercial vehicle safety technologies present new opportunities for management and logistics in the road transport industry. As with many emerging technologies, the link to opportunity beyond the designed purpose of a particular technology is not fully realised until after implementation. This paper explores the relationship between on-board safety technology, management and logistics within the trucking industry. Topics discussed include best practice fleet safety management, safety culture, safety-related technologies. It includes the results of a survey of fleet safety executives and drivers about the effectiveness of safety technologies and effectiveness ranking. A literature review on the effectiveness of fleet management techniques that encourage safety culture and performance is included. The ability for on-board safety systems to support logistics and multimodal transport are discussed. Of the technologies currently available, electronic logging devices were found to be the most promising technology for transformational change in the context of safety, management and logistics.

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Introduction

The road transport industry has experienced increased acceptance of safety technologies presenting commercial vehicle fleets with safety management and logistics opportunities. Many early adopters of safety technology have combined this investment with advanced safety management practices. For the purpose of this paper, to distinguish fleets that invest in advanced safety technology and management systems from average fleets, the acronym SAFER “safety adoption for economic return” will be used. SAFER fleets are equipping their trucks with many active and passive safety technologies, either as original equipment or aftermarket components. To optimise safety benefit from the investment in these technologies, SAFER fleets are also taking the following steps:

a) Giving higher scrutiny to company safety policies and practices.

b) Raising safety standards including what qualifies as an accident or mandating lower speeds in adverse weather and traffic.

c) Monitoring, measuring, and correcting driver behaviour through predictive modelling and “score-carding” supported by safety technology data, and

d) Strengthening driving training systems with the use of safety technology feedback.

As a result of combining safety technologies with improved safety management policies and protocols, SAFER fleets have a strong record of safety performance and therefore these exemplar fleets provide excellent insight into how safety technology interacts with managements and logistic operations.

This paper will examine the link between safety technology implementation with safety outcome based on case study data from SAFER fleets. It will also examine from literature, best fleet safety management practice to differentiate actions that work well from those that do not. Based on these findings, the interplay of safety technology and management practice can be explored in the following manner.

- a review of fleet safety management and culture
- a listing of safety-related technologies currently available
- the relationship between safety technology investment and safety performance
- the integration of safety management and technology
- current roles and challenges for commercial vsehicle management technologies
- vehicle based systems supporting multi-modal freight movement
- new operational horizons with transformational technology
- barriers to the deployment of transformational technologies.

The relationship between safety technology and management practice

To establish the relationship between safety technology and management practice, it is necessary to distinguish safety management characteristics that produce successful outcomes from those that are counterproductive. By establishing safety management best practice, it is possible to link safety technology features that can be used in conjunction with fleet management operations to maximise safety outcome. The following is a literature review of safety management practice, including fleet safety culture, identification management techniques that work and aspects of driver training that have proven to be successful. Also included is an examining of driver safety problems and driver simulation training related to advanced safety technology.

Safety culture defined

What is organisational culture? In one report, organisational culture was defined as the "norms, attitudes, values, and beliefs held by members of an organisation." Another description is "the prevailing ideology that people carry inside their heads. It conveys a sense of identity to employees, provides unwritten and, often, unspoken guidelines for how to get along in the organisation, and enhances the stability of the social system that they experience." In short, organisational culture consists of the beliefs within an organisation of what is important and how things work within the organisation to produce the way things are done within the organisation.

All organisations have a culture. It may be explicit, with a clearly stated mission, defined objectives and goals, a manual of procedures, and an organisational structure and leadership to execute the mission. Or it could be implicit with no clear mission, fixed objective, or discipline in pursuing it. But all organisations, for better or worse, have a culture. "Safety culture" is simply the organisational culture applied to safety.

So, what is "safety"? Safety is broadly defined as the condition where adverse events are avoided and actions and procedures are implemented to prevent them (Short, Boyle et al., 2007). Developing a safety culture begins with the understanding that all "adverse events," be they traffic crashes or slip-and-falls, can be prevented or at least mitigated. Some authors have claimed that the term "accident" implicitly carries with it the implication of an event that cannot be prevented. The evidence is weak and the insistence on purging the word a distraction, but the point that there must be a commitment and purpose to eliminate all accidents, or hazardous events, is entirely valid and well-supported throughout the literature as critical to developing a safe work environment.

One author defined five components to develop a comprehensive safety culture

1. organisational commitment, defined by top management adopting safety as a core value
2. consistent management involvement, monitoring, supervising, and directing for safety
3. a reward system for safe behaviour and achievements
4. empowering employees to promote safety and take action
5. a reporting system to evaluate levels of safety and identify areas for improvement.

A perception that may hinder a comprehensive and consistent approach to promoting and building safety is that profit may not align with safety. Yet there is general agreement from the safest carriers that safe operations are an important component of business success. In one survey of safety managers, the financial impact of traffic accidents, in terms of the economic costs of the crash, litigation costs, as well as reputational costs with customers and drivers, were the strongest motivations identified for safety (Peng, Boyle et al., 2010).

Applying the organisational culture to safety implies that the commitment to safety must be reflected throughout the organisation, from the top leadership to the frontline worker and in all departments and across all functions of the organisation. In one case study, a carrier made all units accountable for the safe operations of the company, not just limited to the safety department. For example, the sales department had the affirmative responsibility to determine if a prospective job could be safely moved within the time allotted. So the responsibility for safety went beyond the safety department, to include marketing, sales, dispatching, vehicle maintenance, the driver, and so on (Short, Boyle et al., 2007).

Developing and maintaining a culture of safety

Safety culture is developed by leadership, not just through one-on-one interaction, but also through official policies, memos, e-mails, mass communication. Studies that show that the desired safety culture has to be communicated and developed intentionally (Short, Boyle et al., 2007). Organisations that value safety and communicate that value effectively through supervisors and managers to drivers, operate more safely and have drivers with higher motivations to drive safely (Newnam, Griffin et al., 2008; Peng, Boyle et al., 2010). A recent high-level synthesis of literature on safety culture recommended the following actions to develop or enhance safety culture (Short, Boyle et al., 2007):

1. Develop a specific statement of safety culture, appropriate to the mission of the carrier.
2. Conduct an analysis of the threats to safety and potential vulnerabilities.
3. Identify and dispel myths: Some drivers still report that they won’t wear safety belts to prevent being trapped in the truck.
4. Develop institutional knowledge of safety, through:
    a) Training, to build the knowledge base
    b) Analysing both safety successes (crash-free drivers) and failures, including crashes and near-crashes for how they can be avoided
    c) Mentoring to take advantage of experienced, safe drivers to transmit the safety culture to new drivers.
5. Be explicit about the safety roles of all employees, from top to both.
6. Assess the effectiveness of safety communication throughout the corporation.
7. Build an effective data system to store and evaluate safety outcomes.
8. Develop and use on a continuing basis training and motivational tools to enhance safety.
9. Develop tools to promote retention of the best drivers, through incentives. A consistent theme in the literature is to provide a clear career path to advancement, as well as pay, rewards for safe behaviour, and empowerment (the ability to use reasonable judgment to make safety decisions.)

One survey of safety-conscious managers ranked the following as the most important in reducing crash rates and promoting safe operations (Adapted from [Knipling, Hickman et al., 2003]):

1. regular vehicle maintenance and inspections
2. hiring based on driver history of crashes and traffic violations
3. continuous tracking by driver of crashes and traffic violations

4. requiring at least two years of driving experience for new hires
5. carrier investigation of crashes and loss incidents
6. standard training for all new hires
7. carrier management aligned to promote safety in all functions.

Finally, several reports and case studies emphasised the need to collect good data on safety outcomes, to monitor results, and to continuously evaluate the data to identify problem areas. (e.g., Knipling, Hickman et al., 2003). One telling example came from (Short, Boyle et al., 2007). An oil tanker fleet reduced incidents of running aground by 99% through an analysis the incidents, identifying multiple factors that contributed, and reducing them through training and changes in practices. Truck crashes obviously occur in a different environment (e.g., the contributions of other drivers on the road, among many other things), but the example points up the potential of substantial improvements from thorough analysis.

What works

- messages from the top leadership through the departments to drivers
- consistent verbal communication
- participation and buy-in for all departments, not just the safety department
- internal cooperation across departments
- education and training on how to do things right
- balanced positive and negative reinforcement
- demonstrated management commitment to safety
- screening during hiring
- simple, consistent, repeated safety messages

What does not work

- a culture of fear
- termination threats
- "customer is always right" attitude, because sometimes the customer is wrong about safety
- adversarial approach to training ("cop and robber") as opposed to a coaching approach
- incentives without recognition
- generic safety programmes
- pretending compliance is the same thing as safety.

(adapted from [Short, Boyle et al., 2007])

Driver selection, training, and retention

Hiring and retention practices were deemed essential to building a safe driver population. There is general agreement that driver selection is critical. This only makes sense in light of the common perception that 90% of crashes are caused by driver error. While oversimplified, it does make the point that the driver is the last part of the system that can avoid a crash. A well-trained, well-rested, and careful driver can reduce crash risk substantially (Mejza, Barnard et al., 2003). The following is a prioritised list of safety challenges identified by a survey of safety managers. While this is from one survey, the list represents a common perception (Knipling, Hickman et al., 2003):

1. unsafe driving, such as speeding & tailgating
2. high-risk drivers
3. driver health and wellness, lifestyle & general health, including sleep apnea
4. lack of defensive driving skills
5. delays from loading and unloading, which results in long hours
6. driver fatigue
7. aggressive driving
8. driver turnover, resulting in an unstable workforce.

Seven of the eight top safety problems related to drivers, of which three related to driver behaviour (unsafe driving, high-risk drivers, and aggressive driving). Two related to driver health and wellness, including driver fatigue; one was potentially addressable by training (lack of defensive driving skills); and the final one related to driver retention.

Examining driver safety problems

Safety managers, in considering the top safety problems they face, tend to focus on drivers as a critical component in the level of safety. A recent survey of safety managers showed a general belief that getting the right, safe drivers was among the most important tools in achieving safe outcomes, even more than training, company communications, and rewards and discipline. In terms of practices, the safety managers believed that creating a positive safety culture in which driver jobs are valued was essential in attracting high-quality applicants and enable selective hiring. Recommended hiring practices included assessing the “whole person” to identify good employees as well as safe drivers; assessing past record especially serious traffic violations and crashes; include criminal background checks; road driving test with a standardised checklist; assess driver personality traits such as aggressiveness, impulsiveness, and attitudes toward risk; hire for the long haul, as longer-term drivers tend to be safer; maintain detailed files on each driver; and use probationary periods for new hires (Knipling, Burks et al., 2011).

Multiple authors have noted that poor existing driving records are predictive of future crashes, particularly at-fault crashes and alcohol/drug-related crashes. A study of driver records identified the following traffic violation types as substantially increasing the probability of future crashes: Improper lane change; failure to yield, improper turn, and failure to maintain lane. Each of these involve vehicle control or failure to yield right of way (Knipling, Hickman et al., 2003; Murray, Lantz et al., 2005). In terms of hiring, safety-focused carriers focus on the following indicators in making hiring decisions (adapted from [Knipling, Hickman et al., 2003]):

- prior record of crashes and traffic violations
- lack of dismissals for alcohol or drugs
- lack of past at-fault crashes
- prior driving experience
- recommendations from other carriers.

Mejza, Barnard et al. (2003) identified the “safest” carriers, using the MCMIS data, and surveyed them on safety practices. The carriers were identified mainly by low crash rates. The results showed they consistently screened for safe drivers; used extensive training both for new hires and for veteran drivers; trained both company drivers and owner-operators; trained on a wide scope of issues; and used different types of incentives to reward safe driving. In terms of driver selection, most important factors were lack of alcohol or drug violations; lack of prior crashes, speeding tickets or other moving violations, and driving experience with other carriers. In terms of driver personality traits, honesty, reliability, self-motivation, and self-disciplined were the most important characteristics (Mejza, Barnard et al., 2003).

The degree of driver turnover in carriers was identified as both a problem and an opportunity. It is a problem if strong drivers are lost. It becomes difficult to build a strong, cohesive culture if new drivers are constantly rotating through. Driver turnover, however, is an opportunity if it is used to weed out weak or uncooperative drivers, and to bring in new, stronger drivers who are trained in the safety culture of the firm. In fact, some carriers prefer new drivers that they rigorously train in the safety culture of the carrier (Knipling, Hickman et al., 2003; Short, Boyle et al., 2007). Retention is increased through driver compensation and the potential for career advancement. The possibility of career advancement within a carrier was repeatedly identified as a reason for drivers to leave a firm.

Many carriers and safety managers regard driver incentives as an important tool for safe driving. Case studies of highly effective carriers showed that they used such programmes as part of their driver management. The incentives fall into two broad categories. The first is rewards, especially monetary rewards. The second is recognition within the carrier for the accomplishment. One survey showed that companies used a variety of methods, including direct praise, public recognition, letters from management, decorations and cash. In terms of how carriers determined candidates for the incentive (and discipline) programmes, a survey of carriers showed 93% used the crash record, 63% took into account FMCSR violations, 57% traffic convictions, and 48% factored in public complaints (Knipling, Hickman et al., 2003; Mejza, Barnard et al., 2003).

Managing driver training

It is interesting to note that driver training is widely considered essential, but there is relatively little hard evidence that it is effective (Brock, McFann et al., 2007; ATRI 2008). The lack of such evidence does not mean that training is ineffective; more likely it is because such effectiveness is hard to demonstrate. “Effective” should mean not just “able to pass the CDL test,” but rather safer driving, lower crash and traffic violation rates. But showing that crash rates are reduced by driver training is difficult because crashes are relatively rare events and not all truck crashes are preventable by safer driving by truck drivers. Nevertheless, there is widespread agreement that driver training is essential, that merely passing the CDL test is an insufficient qualification to drive a truck safely, and that training is appropriate both for new drivers, new hires, and veteran drivers.

Current driver training is based on a consensus of what experts think it should be. There is a general consensus on what should be taught, but not how the instruction should be conducted or how the results should be evaluated. Four types of skills training are common:

1. range training, driving in enclosed course and the use of skid pads to teach vehicle control in low friction situations
2. driving simulator training to expose drivers to a wide variety of situations
3. demonstration of skills by instructor, including classroom instruction
4. behind-the-wheel training (BTW) with an instructor.

There were no sources found that recommended only one type of training. Most stressed a number of different approaches, including computer-based instruction (CBI), closed course and skid pad training, driving simulators, and BTW. The Schneider trucking company has an integrated training programme that includes classroom instruction, CBI, simulator training, BTW, and homework. Schneider reported that their integrated training regimen for new drivers has increased the graduation rate (75% to 81%), reduced time to go on the job by 38%, and 0 to 90 day decreased the crash rate in the first 90 days on the job from 31% to 10% (Brock, McFann et al., 2007). A survey of the driver training practices of motor carriers from 2004 showed that in-vehicle, on-road training were used by almost 90% of the carriers, both pre-service and in-service. Classroom instruction was used by about 80% of the carriers and two-thirds used training on closed course (Staplin, Lococo et al., 2004).

Behind-the-wheel training is universally considered the best and most effective. The way to learn to drive a truck is to drive one under the supervision of a skilled instructor. BTW training is used both for new drivers and for in-service training of experienced drivers, to make sure their skills stay sharp and that they don’t become complacent. One report indicated that UPS trainers accompany drivers four times per year, with a review to see if the driver has developed bad habits. Driver retraining is mandatory if a driver is involved in a preventable crash (Staplin, Lococo et al., 2004).

Simulator and computer based driver training

The use of simulators generally regarded as effective, often in conjunction with other methods. It is noteworthy that all major airlines use simulators as part of pilot training. Driving simulators range from desktop units to full-motion units. Generally, simulators can be used to expose drivers to hazardous situations so that they can experience the situations safely and be trained in how to react, in a safe environment. There is some anecdotal evidence that their use decreases dropouts and actually improves safety by a measureable amount. The latter claim is from the experience of some transit agencies that used simulators as part of their training. High-fidelity simulators can be used to teach effective scanning and vehicle control in adverse weather. (Some drivers will suffer from simulator-sickness syndrome, which makes driving simulators not appropriate for all drivers.) A European regulatory agency considered one hour of simulator training plus four hours of BTW to be more effective than eight hours of BTW. One study identified competence and enthusiasm of the simulator staff as critical to its success (Staplin, Lococo et al., 2004; Brock, McFann et al., 2007; Morgan, Tidwell et al., 2011).

An advantage of computer-based-instruction is that it can provide a variety of audio-visual information through a variety of mediums: sounds, video, graphics etc. In addition, CBI can be tailored to the individual student’s pace of learning, as well as the content and mode of instructions. However, the effectiveness of CBI, including learning paced to the individual student, that depends on how well-designed it is and whether it includes those elements. There is no particular magic to computer-based learning. However, there is some research that shows that well-designed CBI can increase the amount of information learned and retained (Staplin, Lococo et al., 2004).

One study of truck driver training methods recommended the following the following deployment of different training methodologies:

- Use of CBI for basic instruction. It is considered to better engage the students, reduce training costs, provide more uniform training, free time for hands-on training on the vehicle. Elements include:
    - vehicle control systems
    - pre-, post-, and en route vehicle inspections
    - identifying and maintaining vehicle systems

  - prepping vehicle for adverse weather
  - cargo securement
  - proper lifting techniques
  - effective communication skills.
  - defensive driving through dynamic examples using CBI.

- Use of simulators for defensive driving, docking. High-fidelity simulators can be used to teach effective scanning and vehicle control in adverse weather.
- Use of skid pads to train on stopping distances under different loads; familiarisation with different brake; as well as vehicle control on low-friction surfaces.
- Finish training of solo drivers (1st seat), using one-on-one, over-the-road training using company drivers, tied to performance based criteria.

Key elements of management practice linked to safety technology

On-board safety technologies such as ESC, Forward collision control and braking, forward facing and inside cab facing cameras, over-speed alert systems and electronic logging devices provide direct digital feedback to fleet safety management providing critical information on driver performance. Such information can be used to support the following functions.

1. Consistent management involvement, monitoring, supervising, and directing for safety.
2. Reward systems for safe behaviour and achievements.
3. Reporting systems to evaluate levels of safety and identify areas for improvement.
4. Analysis of the threats to safety and potential vulnerabilities.
5. Development of knowledge bases, analysing both safety successes (crash-free drivers) and failures, including crashes and near-crashes for how they can be avoided.
6. Mentoring to take advantage of experienced, safe drivers to transmit the safety culture to new drivers.
7. Build an effective data system to store and evaluate safety outcomes.
8. Develop and use on a continuing basis training and motivational tools to enhance safety.
9. Develop tools to promote retention of the best drivers, through incentives.
10. Educating and training on how to do things right.
11. Demonstrated management commitment to safety.
12. Unsafe driving, such as speeding & tailgating.
13. Reduce high-risk driving.
14. Improve defensive driving skills through coaching.
15. Monitoring delays from loading & unloading, which results in long hours.
16. Monitoring driver fatigue.
17. Reduce aggressive driving.
18. On-road complement for driving simulator training to expose drivers to a wide variety of situations.

19. Behind-the-wheel training.
20. Defensive driving through dynamic real-world examples.

List of on-board safety technologies

The following safety technologies are available to the transport industry. For the purposes of this report, they are treated as generic with no brand or trade names.

1. Stability control – This includes electronic stability control (ESC) and rollover stability control (RSC). These technologies work in the background and will automatically de-throttle the engine, and initiate braking without driver involvement when the system detects loss of control or vehicle over-speed in a curve.
2. Lane keeping/departure – Monitors vehicle lateral position in the travel lane and issues a warning if the vehicle begins to leave the travel lane. The system deactivates when the driver uses the turn signal indicator during a lane change manoeuvre.
3. Over-speed alert system – This system uses GPS and an electronic map containing posted speed limit data, and issues an alert if the driver exceeds the posted speed limit on a particular road section.
4. Adaptive cruise control – Uses radar and in some cases integrated vison systems to monitor the traffic ahead of the vehicle containing the technology. The driver selects a cruising speed and the system monitors the gap to the lead vehicle. When the following distance become too short, the engine is de-throttled and if necessary brakes are applied automatically.
5. Forward collision control and braking – This technology uses the same sensors and control systems as adaptive cruise control. Forward collision control and braking operates in the background. When a potential forward collision is identified, the technology warns the driver. If the condition persists and a collision is imminent, the system will apply the foundation brakes to reduce the impact speed.
6. Electronic log book - Electronic logging devices (ELDs) monitor driver hours of service to improve compliance with the safety rules that govern the number of hours a driver can work.
7. Automated transmissions – These are often referred to as automated manual transmissions. They eliminate the need for the driver to change gears while in forward motion. These systems behave similar to an automatic transmission in an automobile.
8. Disc brakes – Disc brakes use a rotor disc and a set of friction pads in place of the old style brake-drum and brake-shoe systems often referred to as “S” cam brakes. They have superior brake performance and do not have the brake out-of-adjustment problems associated with the “S” cam brake systems.
9. In-cab cameras – These cameras are focused on the driver and are triggered during hard braking or significant lateral- or steer-events. Fleets have the option of having film clips associated with triggered events captured for review, which may be used for study, driver coaching, and legal defence.

10. Forward facing cameras - These cameras are focused on the road ahead of the vehicle. The systems are triggered during hard braking or significant lateral- or steer–events, or by driver request. Fleets have the option of having film clips associated with triggered events captured for review, study, driver coaching, and legal defence.

Innovative evolution of safety technologies supporting management and logistics

On-board safety technologies present new opportunities for management and logistics in the road transport industry. As with many emerging technologies, the link to opportunity beyond the designed purpose of a particular technology is not fully realised until after implementation.

Electronic logging devices (ELD) are likely the best example of a single purpose safety technology that has experienced unanticipated innovation. Once these devices entered the commercial market, innovative forces within the private sector integrated additional features such as GPS, information dashboards and management databases that allowed for enhanced awareness of the driver and vehicle activity. This information is now used to support management and logistics functions:

As expected these technologies have greatly reduced driver paperwork and have injected discipline into driver hours of service (HOS). However, the unanticipated benefits include.

- data keeps dispatchers up to date on driver and delivery statuses
- provides dispatchers with early identification of potential HOS violations
- identifies drivers in real time who are already in violation
- provides data on available hours left per driver to complete jobs
- determines if driver hours contribute to inefficient vehicle use
- create comprehensive driver coaching programmes based on HOS violation trends
- continually assess job assignments to improve efficiency.

Other ELD system innovations include the ability to create customisable driver task lists and driver service forms, provide continuous updates between drivers and dispatch, and integration with dispatch systems resulting in automatic flow of trip information, status updates, and completed forms.

ELDs from well-known GPS device providers integrate mapping systems with commercial turn by turn navigation that takes into account vehicle road restrictions such as weight, length, width, and height, as well as hazardous materials (HAZMAT) routing. Lane position features helps to place the vehicle in the proper lane well ahead of the exit or fork in the road. Active traffic routing reroutes the vehicle in the event of congestion and road work.

There is also direct messaging between the driver and dispatch and vehicle inspection reporting where the mechanic can easily see that there is a problem with one of the vehicles in the fleet. Alerts can be generated to email or text messaged to a cell phone letting the mechanic or fleet manager know that there is an issue.

Other safety technologies provide support for safety management and logistics through communication of significant events such as heavy braking or quick lane changes:

- over-speed alert system
- ESC
- forward collision control and braking
- in-cab cameras
- forward facing cameras

With these systems, the fleet safety officers are provided alerts that indicated vehicle operation beyond expected norms. In the case of on-board cameras, video footage is uploaded usually to a third party contractor who evaluates the particular event and notifies the fleet when risky driving behaviour is identified. SAFER fleets use this data constructively to provide individual training to the particular driver. Fleets that initially used this data for punitive action report poorer acceptance of the technology and poorer behaviour modification outcomes. When the policy was altered to focus on driver training, acceptance of the technology improved.

Management practices reliant on safety technology

Measuring the effectiveness of advance safety management systems

Insight into the effectiveness of safety technology was achieved through case study of seven SAFER fleets (Woodrooffe, 2017). This study included onsite interviews of fleet safety managers and a formal survey of approximately 1 000 drivers. The survey was conducted in accordance with the University of Michigan University of Michigan Health Sciences and Behavioural Sciences Institutional Review Board approval process and the completed surveys were coded by the University of Michigan Institute for Social Research. The findings from the company interviews and safety system analysis were combined with the results of the survey to determine what safety technologies were considered most effective and to determine what safety management policies and practices provide the best safety outcome. The study also provides an estimate of the relative benefits associated with safety technology and active safety management practices.

The SAFER companies participating in this study are heavily invested in safety technology and have active safety management programmes. Consequently, these companies have very few crashes. To assess the safety performance of exemplary companies, it was determined that crash frequency and travel exposure data were not robust enough to generate reliable crash rates. As an alternative means of assessing safety performance, selected Compliance, Safety, Accountability (CSA), Behaviour Analysis and Safety Improvement Categories (BASICs) were used. These measures are generated by Federal Motor Carrier Safety Administration (FMCSA) as part of their safety compliance and enforcement programme. They provide a reliable independent means of assessing safety performance that can be applied to any fleet for comparative analysis (FMCSA “Safety Measurement System).

To assess company safety performance for this particular study only the following select BASIC measures were used: unsafe driving, hours of service and vehicle maintenance. For the purpose of this paper these metrics are considered to be the most direct and reliable for quantifying company safety performance over a broad spectrum of carriers. For example, it allows direct comparison using identical metrics for carriers hauling hazardous materials and non-hazardous materials. The comparative safety score metric was defined as the aggregate of the selected BASICs listed above.

Safety Score = unsafe driving + hours of service + vehicle maintenance

The participating SAFER fleets were identified A through G. The safety scores of the participating fleets are shown in Table 1. Safety technologies deployed by the participating fleet is shown in Table 2.

Table 1. **Safety scores of fleets participating in study**

(4 year average)
Lower score indicates better safety performance

Fleet	Safety score
A	21
B	45
C	33
D	17
E	57
F	68
G	21

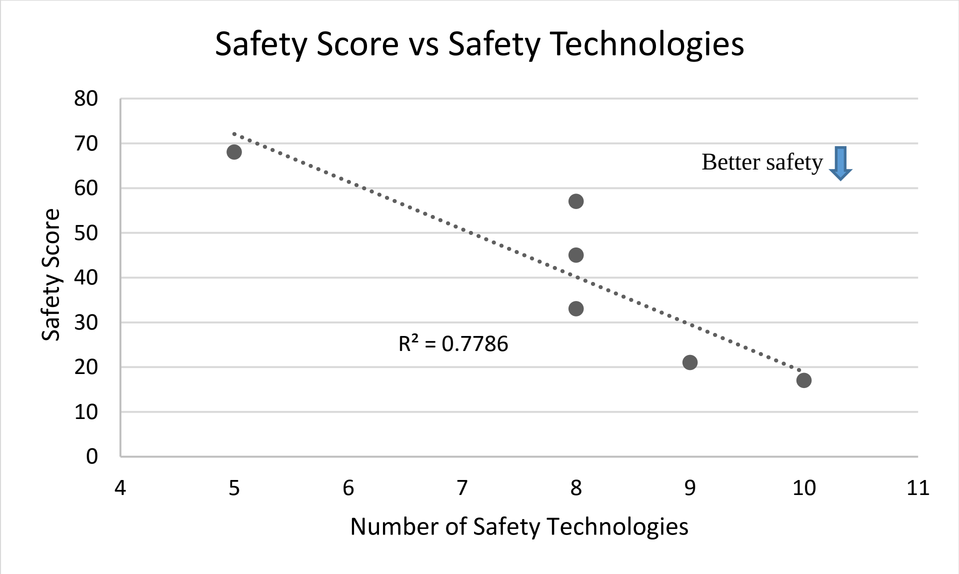
Table 2. **Safety technologies in use by participating SAFER fleets**

Company	ESC	LDW	FCAM	ICC FCC	Blind spot det	Disc brakes	AMT	Safety telematics e-log	Speed Limiters	Speed monitoring with GPS
A	yes	yes	yes	yes	yes	yes	yes	yes	58 mph	no
B	yes	yes	yes	yes	no	yes	yes	yes	67 mph	no
C	yes	yes	yes	yes	yes	no	yes	yes	62 short	no
D	yes	yes	yes	yes	yes	yes	yes	yes	65mph	yes
E	yes	yes	yes	no	yes	yes	yes	yes	65mph	no
F	yes	no	no	no	no	yes	yes	yes	63 mph	no
G	yes	no	no	yes	no	no	yes	Yes	68mph	no

ESC – Electronic stability control
LWD- Lane departure warning
OSA - Over speed alert
ACC - Adaptive cruise control
ELB - Electronic log book
FCAM - Forward collision avoidance and mitigation
AMT – Automated manual transmission
DB – Disc brakes
ICC– In-cab cameras
FFC – Forward facing cameras

Combining data from Table 1 and Table 2 shown in Figure 1, we find the amount of safety technology investment per truck is a strong indicator of overall fleet safety performance. Safety technology investment appears to have direct safety benefit on its own merits but it may also be a surrogate for commitment to safety by the fleet owner. It is likely that in addition to the investment in technology these fleets also deploy leading safety management practice analytics that promote improved safety culture and performance.

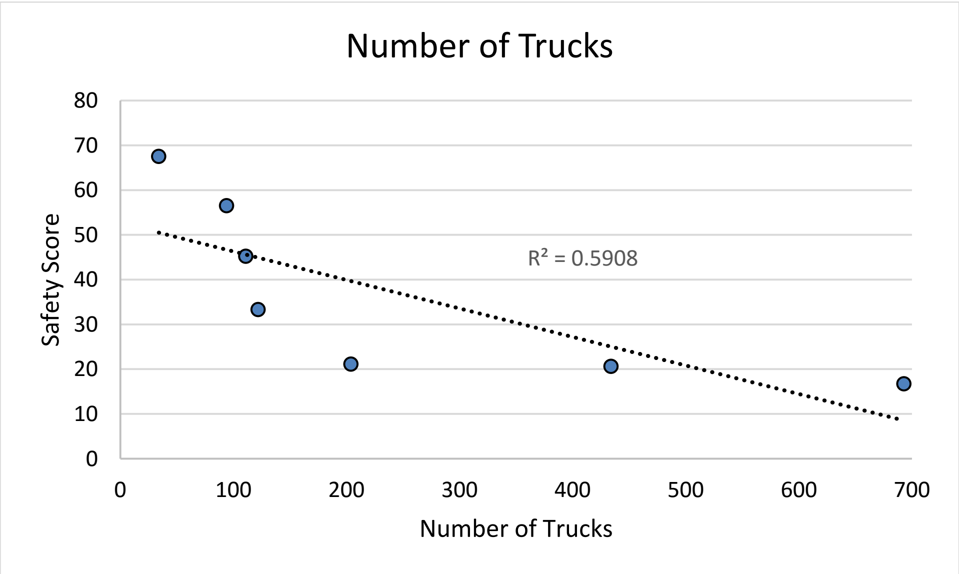
Figure 1. **Number of safety technologies installed per truck to safety performance**
(Lower score is better safety performance)



Influence of fleet size on safety technology and management performance

The data in Figure 2 shows a correlation between truck fleet size and safety score. The reason for this relationship is almost certainly that larger SAFER fleets are more likely and capable of having more resources focused on safety. Smaller companies are less likely to have the resources to provide staff devoted exclusively to safety. This speaks to the integration of technology and safety management suggesting that, for the population examined in this analysis, fleets greater than 200 trucks will likely be more successful in achieving higher safety performance than fleets with less than 200 trucks. This finding underscores the important role that management and technology play in improving fleet safety performance.

Figure 2. **Relation of fleet size to safety performance**
(Lower score is better safety performance)



Driver acceptance of on-board technology

Consensus of opinion of safety directors from SAFER companies regarding the value and effectiveness of technology was achieved during the course of the study. Technology was classified as being either dependent or independent of the driver and or management action.

- Dependent technology requires that there is effective driver and or management intervention in conjunction with the technology in order to get substantive safety value.
- Independent safety technology provides the majority of its safety value without driver and or management intervention.

Table 3 below lists consensus view of safety technology value based on the opinion of SAFER drivers and Table 4 by participating company safety executives. The technologies were grouped into three categories highly effective technology, effective technology and less effective technology.

Table 3. **Driver survey ranking of acceptance and satisfaction with safety technology**

Technology	Accepted	Satisfied	Rank
Highly Effective Technology			
Disk Brakes	91%	86%	1
Auto Transmission	79%	71%	2
Electronic Log Book	91%	69%	3
Effective Technology			
Stability control	74%	59%	4
Adaptive cruise control	74%	57%	5
Forward facing Cameras	77%	55%	6
Speed monitoring with GPS	66%	52%	7
Forward collision control and braking	66%	49%	8
Lane keeping/departure	65%	43%	9
Less- Effective Technology			
In-Cab Facing Cameras	48%	32%	10

Drivers appear to value most frequently used technologies specifically, disk brakes, automatic transmissions, and electronic log books. Safety executives agree with these but they also consider stability control, forward collision control and braking, in-cab and forward facing cameras with coaching, adaptive cruise control, speed monitoring with GPS in the highly effective category. Interestingly, drivers value automatic transmissions highly but safety executives value them as moderate.

Drivers and safety executives consider lane keeping/departure, forward cameras as moderately effective. Drivers also include stability control, adaptive cruise control, speed monitoring with GPS, forward collision control and braking in the moderate category.

Drivers and safety executives agree that in-cab facing cameras have low effectiveness however, if coaching is included with the in cab facing camera, then safety executives rate them as highly effective.

Table 4. **Company safety executive consensus on technology value**

Safety Technology	Type	Safety effectiveness
Highly Effective Technology		
Stability control	Independent	High
Forward collision control and braking	Independent	High
Disk brakes	Independent	High
In-cab and forward facing cameras with coaching	Dependent	High
Adaptive cruise control	Dependent	High
Electronic log book	Dependent	High
Speed monitoring with GPS (identifies speed zones)	Dependent	High
Effective Technology		
Lane keeping/departure	Independent	Moderate
Automatic transmission	Independent	Moderate
Forward cameras only with coaching	Dependent	Moderate
Less Effective Technology		
In-cab and forward facing cameras no coaching	Independent	Low
Forward cameras only without coaching	Independent	Low

New roles for multi-modal freight movement related to on-board technology

Multimodal Freight

FHWA recently published the results of a national multimodal freight analysis framework research workshop (Berthaume and Morton, 2015). The high level workshop focused on the National Multimodal Freight Analysis Framework. During the workshop, participants discussed a variety of opportunities for improving the data, analysis, and modelling of freight travel at the national level. Two potential research directions that surfaced in this workshop were as follows:

1. Behavioural-based (or agent-based) national freight-demand modelling could represent a significant step forward. Seasonal change, the impact of business decisions, and other variables that have been previously unaddressed, could be incorporated in a meaningful way.
2. Freight data development and enhancement is required to create a more detailed predictive model using higher quality data. New methods of data collection and integration could represent a significant advancement.

Freight analysis framework: Future direction

Workshop participants offered potential research area categories of data and modelling. The National Multimodal Freight Analysis Framework dataset is based on a national-scale compilation of different surveys and field databases, therefore challenges with the data include:

- applying the data for reasoning, "what if?' scenario analyses, and trend or pattern study
- provisional and future year estimation
- inadequate cost and temporal factors
- calibration and validation problems are due to a lack of reference data
- insufficient geographic scale
- data deficiencies of coverage, aggregation, sparseness, consistency, and accuracy.

Workshop participants concluded that an important modelling component would be the accurate capture of transfers among modes.

Addressing freight data challenges

To address freight data challenges, participants noted that new innovations in data development and its management are needed. The research outcome in the form of nationwide, disaggregated freight-flow data will feed a broad range of further studies and applications. One of the major beneficiaries is on the freight-travel demand model improvement side. The future freight system will likely require demand model development that is national supply-chain–based with comprehensive multimodal freight-travel. The systems approach could extend its capacity by supporting national and regional freight policy making, strategic scenario analyses, and future freight and economic impact estimations in a timely manner. Improved modelling could aid in economic impact studies, road maintenance plans, cost–benefit analyses, air quality, and toll or pricing studies. Major economic sectors and industries, including general public domain, could also benefit from the geographically detailed, cost-sensitive, and temporal nature of datasets on their policy and decision making.

Freight analysis framework issues

Although freight system analysis has many strengths and benefits, there are also issues to be addressed. These issues include:

- The National Multimodal Freight Analysis Framework objective should be reviewed and examined on a continual basis. Areas such as Federal, State, and local roles and needs, private (rail) business and public–private (highway–truck) co-dependency, as related to multimodal exploration, should be considered.
- Many datasets from different sources and in different formats are combined to create the freight analysis framework. Gaps and level of detail constrains the analysis suitability to mainly national and regional scale analysis. To fill the gaps, advanced statistics and fitting methods are needed along with expert judgment and adjustment.

State level multimodal case analysis

With the widening of the Panama Canal, the State of Florida has been focusing on improving multimodal interoperability (Feigenbaum, 2014). The principle goals of the programme are to reduce freight congestion and increasing state-wide economic development. Trucks still transport more freight than any other mode; however it is necessary to evaluate how trucking interacts systematically with other freight modes. Combining these modes improves our multimodal planning.

One structural challenge comes in understanding the needs of the individual modes of transportation, on the regional and state-wide scale. The goal is to implement strategies which best fit each mode, while still focusing on multimodal advancement. Another challenge in transitioning from a modal perspective to an intermodal model is integrating state policy with the direction of the U.S. DOT and federal policy. To address these challenges, Florida has worked to develop partnerships on the national level by collaborating with the U.S. DOT, the American Association of State Highway and Transportation Officials (AASHTO), and the Federal Highway Administration (FHWA).

It is clear that the U.S. DOT, in partnership with state DOTs should emphasise the importance of freight and of freight planning, connecting freight to the daily lives of the general public. Correct investments are being made but if the public does not understand why, the importance of the efforts is diminished. Participating in public outreach campaigns sets the context for what freight is, and how freight is important to the economy and quality of life. The economic benefits of efficient freight movement should be detailed.

Although structural challenges between the state and federal level exist, the trend is toward more integrated freight planning. The U.S. DOT has made positive steps in implementing innovative transportation policy, including the Moving Ahead for Progress in the 21st Century (MAP-21), which is setting real standards for freight planning. MAP-21 authorised the State Freight Advisory Committee to assist the U.S. DOT in developing a National Freight policy, and Florida was one of the first states to provide information and begin state freight planning and performance efforts.

For rail, Florida has the intermodal container transfer facility project at Port Everglades. A new freight rail line constructed to the port to reduce congestion at the port and further down at the rail terminus was opened in 2014. It is estimated that the investment will reduce congestion on interstate highways and local roadways by diverting an estimated 180 000 trucks from the roads by the year 2029.

Unified documentation

One pressing need for international multimodal transport is to unify documentation and reporting systems. On-board technology such as some Electronic Logging Devices already have the ability to handle electronic shipping forms but there is a lack of standardisation. Transport companies, governments and enforcement authorities are promoting IT devices to ensure better transport logistics with a view to sending and receiving more accurate information during the transport process, tracing vehicles, reducing time-consuming paperwork, speeding up administrative affairs and finally improving traffic flow and reducing congestion (IRU, 2016). The goal is to achieve an internationally compliant system that the transport of goods is:

- safe
- compliant
- sustainable
- paperless
- unencumbered by red tape
- reliable, cost-effective, timely (fast if needed, slow if possible…).

Technical working groups are being established to achieve the following

- **Standardisation and interoperable data** in order to have smooth information flows between all modes of transport, where stakeholders avoid duplication of data specific to each leg of the transport, without forgetting the liability required on each transport leg.
- **Protecting and securing information/data**, where a climate of trust needs to be established, in order for all players to be able to identify a consignor, a carrier or a consignee. The technical group shall also identify the liability for the quality of data submitted or transmitted.
- **E-documents** as paperless transport documents have a considerable impact on cost and reliability of data - fewer errors due to non-duplicated manual entry.
- **Increased data sharing** and new business opportunities, as there is a need to establish recommendations in order to improve access to data, which would ease transmitting orders and forecasts, providing real time information on shipment status and also event management.

Some encouraging institutional steps have been taken to remove barriers. For example, in 2013, the United Nations Convention on the Contract for the International Carriage of Goods by Road addresses various legal issues concerning the transportation of cargo by road has been ratified by 55 countries. The document supports cooperation between carriers and other commercial partners using road transport. An additional protocol to the convention was developed to allow for electronic documents. The benefits for the stakeholders include: financial benefits, transparency, traceability, legal compliance, integration with other services, increase of overall logistics efficiency (less CO_2) and road safety (information about vehicle, load and driver to emergency services).

The underlying theme regarding multi-modal freight movement related to on-board safety technology is the need for accurate and timely data and information systems and shipping forms that are standardised and are internationally compatible with all transport modes. It appears that the electronic log book (electronic logging device) platform offers a means of achieving standardised information and data for use in multi-modal freight movement.

Barriers to the deployment of transformational technologies

Barriers to the deployment of transformational technologies are often unseen because transformational technologies tend to be inventive rather than planned. The automobile, trains, flight and even the telephone are examples of transformational technologies that could be imagined but were not planned or realised until transformational inventions occurred. Therein lies the challenge of identifying barriers to the deployment of transformative technologies. Application of the invention is organic and at some point on the continuum of development, the technology gains acceptance on its own merit. Only after general acceptance does standardisation and policy designed to remove barriers enter the frame to ensure that these new systems function predictably for the benefit of society.

When considering the matter of on-board technology for enabling safety management, logistics and intermodal transport, the main barriers appear to be a lack of system clarity and standardised requirements due to the early stage of transport system digital integration. The experience with electronic log book regulation has shown that a rather modest technology could emerge as transformative primarily because of private sector development of new features that can support system wide integration of real-time transportation data to facilitate efficiency, logistics and intermodal transport.

Data sources and the volume of data are increasing and as a consequence there is a lack of data discipline and uniformity confirming that effort is needed in the area of standardisation data integration. These are high level issues that can be driven by policy and standards that set rules for uniformity.

In conclusion, the underpinning requirement for the deployment of transformational technologies is to have well defined national freight transportation policy in the area of data use, digital operations, modelling and metrics.

Conclusions

This paper examined the relationship between on-board commercial vehicle safety technology with the enablement of management, logistics and intermodal freight. The literature review of fleet safety performance found several best practice management initiatives that can be supported by on-board safety technology. Part of the analysis relied on case studies of seven SAFER fleets involving on-site interviews with safety executives and a driver survey focusing on safety technology acceptance, driver attitude and management practice. While the number of fleet examined was small, they all have a strong commitment to safety and for the most part, could be classified as exemplar in terms of safety performance. The findings on fleet safety should be interpreted as instructive based on fleets having successful safety performance rather than an examination of nationally representative fleets.

1. The number of safety technologies per truck is a strong indicator of overall fleet safety performance. The more safety technology installed on the vehicle, the better the safety performance.
2. Fleet size was found to have an influence on safety outcome in that smaller fleets, less than 200 trucks, likely do not have the economy of scale to devote personnel exclusively to safety management. This finding underscores the important role that management and technology play in improving fleet safety performance.
3. On-board safety technologies such as ESC, forward collision control and braking, forward facing and inside cab facing cameras, over-speed alert systems and electronic logging devices that provide direct digital feedback to fleet safety management were found to support management practices reliant on safety technology.
4. On-board safety technologies present new opportunities for management and logistics in the road transport industry. As with many emerging technologies, the link to opportunity beyond the designed purpose of a particular technology is not fully realised until after implementation.
5. Improvements in multi-modal freight movement related to on-board safety technology will require accurate and timely data to support information systems. Standardised shipping forms that are internationally compatible with all transport modes have been identified as an important requirement.
6. Electronic logging devices are likely the most promising technology for transformational change in the context of management and logistics functions.

7. It appears that the electronic log book (electronic logging device) platforms offer a means of enabling standardised information and data for use in multi-modal freight movement. The identified focus for future development includes standardisation and interoperable data, protecting and securing information/data, e-documents as paperless transport documents, and increased data sharing.
8. Barriers to deployment for enabling safety management, logistics and intermodal transport include a lack of system clarity and a lack of standardised international system components and requirements.

References

ATRI (2008), “A Technical Analysis of Driver Training Impacts on Safety”, American Transportation Research Institute, Arlington, V.A.

Berthaume A. and T. Morton (2015), “National Multimodal Freight Analysis Framework Research Workshop”, Workshop summary report, FHWA-HRT-14-054.

Brock, J.F., J. McFann et al. (2007), “Effectiveness of Commercial Motor Vehicle Driver Training Curricula and Delivery Methods”, Transportation Research Board, Washington, D.C.

Feigenbaum B. (2014), “Creating a Multimodal Freight Program in Florida”, Reason Foundation.

FMCSA (n.d.), “Safety Measurement System” Federal Motor Carrier Safety Administration. https://csa.fmcsa.dot.gov/about/basics.aspx

IRU (2016), “Digital Transport and Logistics Forum Situation”, International Transport Union, Geneva.

Knipling, R.R., S. Burks et al. (2011), “Driver Selection Tests and Measurement: A Synthesis of Safety Practice”, Transportation Research Board, Washington, D.C.

Knipling, R.R., J.S. Hickman et al. (2003), “Effective Commercial Truck and Bus Safety Management Techniques”, Transportation Research Board, Washington, D.C.

Mejza, M., R.E. Barnard et al. (2003), "Driver Management Practics of Motor Carriers with High Compliance and Safety Performance", *Transportation Journal*, Vol. 42/4, p. 14.

Morgan, J., S. Tidwell et al. (2011), “Commercial Motor Vehicle Driving Simulator Validation Study: Phase II”, Federal Motor Carrier Safety Administration, Washington, D.C.

Murray, D., B. Lantz et al. (2005), “Predicting Truck Crash Involvement: Developing a Commercial Driver Behavior-based Model and Recommended Countermeasures”, Alexandria, VA.

Newnam, S., M. Griffin et al. (2008), "Safety in Work Vehicles: A Multilevel Study Linking Safety Values and Individual Predictors to Work-Related Driving Crashes", *Journal of Applied Psychology*, Vol. 93/3, pp. 632-644.

Peng, Y., L. Boyle et al. (2010), “Management's Attitudes Toward Safety in Commercial Vehicle Operations”, Human Factors and Ergonomics Society 54th Annual Meeting.

Short, J., L. Boyle et al. (2007), “The Role of Safety Culture in Preventing Commercial Motor Vehicle Crashes”, Commercial Truck and Bus Safety Synthesis Program. Washington, D.C.

Staplin, L., K. Lococo et al. (2004), “Training of Commercial Motor Vehicle Drivers”, Transportation Research Board, Washington, D.C.

Woodrooffe J., D. Blower and S. Newnam (2017), “Safety Technologies and Management Practice for Improved Fleet Safety”, TRB Annual Meeting.

International Transport Forum
2 rue André Pascal
F-75775 Paris Cedex 16
contact@itf-oecd.org
www.itf-oecd.org