EVALUATING TRUCK DRIVERS' SPEED AND SEAT-BELT USE BEFORE AND AFTER THE IMPLEMENTATION OF A NON-VIDEO ONBOARD MONITORING SYSTEM

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ABSTRACT

Driver behavior, including safe decision-making, can have a direct impact on crash rates and overall fleet safety. According to the Large Truck Crash Causation Study, among crashes where fault was attributed to the CMV driver, the large majority (87.3%) were due to driver error. Of these errors, 38% were decision errors—exceeding safe speeds, for example. Encouraging drivers to make safe decisions, including those regarding speeding and seatbelt use, can reduce equipment and operating costs, and more importantly, save lives. Advances in vehicle kinematic sensors, connectivity to vehicle controller area network (CAN) buses, and video recording devices have led to the advent of onboard monitoring systems (OBMSs). The current study assessed the impact of a non-video OBMS, with in-cab feedback, on driving decisions and behaviors. This before-after intervention study (2-month/4-month) monitored revenue-producing trips in a single fleet in the U.S., during which 20 participating truck drivers drove, collectively, 1.2 million miles. The OBMS delivered real-time driving performance feedback to drivers, and summary reports to fleet managers. Speeding, seatbelt use, and other driving metrics were tracked. A reliability analysis indicated that the OBMS provided speeding and seatbelt violations accurately 86% and 100% of the time, respectively. A trend analysis of violation frequency per 1,000 miles over vehicle operation weeks showed a significant drop in speeding (37%) and seatbelt (56%) violations from the baseline period compared to the first 2-week intervention period. The study found that a non-video OBMS can serve as a useful resource for fleets desiring to improve safety.

KEYWORDS

Driver Monitoring, Commercial Motor Vehicle, Truck, Speeding, Seatbelt

INTRODUCTION

Advances in vehicle kinematic sensors, connectivity to vehicle controller area network (CAN) buses, and video recording devices have led to the advent of onboard monitoring systems (OBMSs). These systems are gaining popularity with Commercial Motor Vehicles (CMVs) as fleets, spurred by liability concerns, seek to maintain awareness of their vehicle's status and drivers' behaviors. The use of these systems to encourage drivers to make safe choices when driving can reduce equipment and operating costs, and more importantly, save lives. Many OBMSs apply continuous video collection or limited-time video collection activated by aggressive vehicle maneuvers triggered by accelerometer sensors. A review of relevant literature demonstrates that evaluations of these systems have been undertaken in various forms over the last 15 years (*1*). However, some areas of study are still lacking, particularly the evaluation of non-video based systems.

BACKGROUND

A key focus of the Federal Motor Carrier Safety Administration (FMCSA) is to provide leadership in the testing and evaluation of promising technologies so that they can be more rapidly implemented and their potential benefits realized in the commercial trucking industry (*2*). The goal of FMCSA's Advanced System Testing utilizing a Data Acquisition System on the Highways (FAST DASH) program is to perform efficient independent evaluations of promising safety technologies aimed at commercial vehicle operations.

This paper focuses on the FAST DASH evaluation of a non-video-based OBMS. Kinematic video-based OBMS technologies provide some advantages in that drivers are often unaware of their level of driving aggression, and video can be used for both post-accident and preventative coaching. However, some potential disadvantages include the fact that these OBMSs can require significant post-processing and, perhaps more significantly, that drivers can experience stress from perceived constant monitoring. A non-video-based OBMS may help fleets encourage a culture of safety while avoiding the perception among drivers of being constantly on camera.

Problem Scope

According to the Large Truck Crash Causation Study, which assessed the causes of and contributing factors to 963 CMV crashes, among crashes where fault was attributed to the CMV (i.e., immediate causes for the critical event making the crash unavoidable are assigned to the CMV), the large majority (87.3%) were due to driver error (*3*). Decision errors—exceeding safe speeds, for example—accounted for 38% of these driver errors. However, little is known about the speeding activities of CMVs among scenarios that do not result in crashes or police reports, or how that behavior may change with in-cab interventions.

A 2013 survey of seatbelt usage, another key safety issue, in the U.S. among medium- and heavy-duty trucks and buses found an overall usage rate of 84%, up from 78% in 2010 (*4*). These data suggest that across the U.S., on average, 16% of truck drivers are still not consistently wearing seatbelts. Again, outside of these surveys, often conducted at controlled environments such as weigh stations, little is known about the typical behaviors of drivers on the road between survey check-points or how that behavior might change with in-cab intervention.

OBMS Technology

A driver monitoring system, the waySmart™ model 820, developed by inthinc® Technology Solutions, Inc., was selected for a FAST DASH evaluation. Without video cameras, this system monitors driving habits such as speeding, aggressive maneuvers (i.e., hard accelerations and braking, severe turning and swerving, and hard bumps), and seatbelt usage through various sensors and data from the vehicle's J1939 or J1708 CAN bus. When the system detects that the driver is speeding, driving aggressively, or not wearing a seatbelt, it issues an in-cab, real-time verbal and audible feedback alert to the driver. The speed and seatbelt alerts are provided to drivers when the performance criteria have been exceeded, and the OBMS allows drivers a brief grace period to correct performance in either of those categories before recording a violation visible to fleet managers. If the driver fails to correct the behavior, a violation is transmitted back to the company's designated reviewer (e.g., safety manager, driver manager). No grace period is applied to aggressive driving violations due to the nature of the instantaneous event, which cannot be corrected before the scenario has ended.

METHOD

The effectiveness of the aforementioned OBMS was investigated using a naturalistic driving study methodology. Naturalistic, or in situ, data collection for the CMV industry involves truck drivers operating vehicles that have been instrumented with data collection equipment, including sensors and video cameras, to record driving performance data during normal revenue-producing routes. The effectiveness assessment was based on a before-after study design, covering approximately 2 months of baseline and 4 months of intervention, to compare drivers' performance before the OBMS's driver in-cab and manager feedback were enabled (baseline) to their performance after the driver in-cab and manager feedback were enabled (intervention). This paper focuses on the safety benefit measures of frequency, and persistence of change in the number of speeding and seatbelt violations that were recorded for each driver per 1,000 miles (1,609 km) between the baseline and intervention period. All study protocols were approved by the Virginia Tech Institutional Review Board.

Fleet

A fleet meeting was selected after considering three factors: (1) the number of trucks and drivers available at the participating fleet; (2) the proximity of the fleet's terminal to both the fleet's and the research team's headquarters; and (3) the fleet management's ability and willingness to facilitate research and vendor team access to the trucks for installation and maintenance of the research equipment. The selected fleet was a midsized fleet operating out of a terminal located in central North Carolina, U.S.A. Both dedicated and for-hire trucks and associated drivers made up the pool for the recruitment of approximately 20 drivers.

Driver Recruitment

The research team worked with the fleet to recruit drivers for participation. Participants were eligible for inclusion in the study if they met all of the following criteria "musts": (i) be at least 21 years old with at least 2 years of professional truck driving experience, (ii) hold a valid Class-A Commercial Driver's License (CDL) with expiration date outside of date range of study, (iii) have a visual acuity of 20/40 or better, (iv) be able to operate a tractor-trailer for the fleet, and (v) be willing to be recorded via video and audio while driving for a 6-month period. Participating drivers read and signed the consent form and received compensation for their participation ($50.00 per week, plus $100.00 completion bonus at conclusion).

Apparatus

Trucks

Twenty-five Class 8 tractors (24 sleeper-berth and one day-cab) were instrumented for this study. The tractors were manufactured in model years 2012 through 2014, and each tractor exclusively hauled 53-ft (16-m) box-van trailers throughout the course of this study. An electronic logging system was pre-installed as part of the fleet's normal operating policy. Additionally, the power units were equipped with electronic-stability and roll-stability control systems. The power units were equipped with standard cruise control, which did not include adaptive cruise technology. The fleet also had a vehicle governor set on each power unit at 65 mph (104.6 km/h) when not on cruise and 68 mph (109.4 km/h) when on cruise.

Data Acquisition System (DAS)

The research team installed all CMVs with VTTI's "NextGen" DAS. The DAS captured three general groups of measures: (1) DAS sensor measures (e.g., Global Positioning System [GPS], lane tracking, yaw rate, 3-axis accelerometer), (2) vehicle network measures (e.g., vehicle speed, brake activation), and (3) add-on measures from the OBMS units (e.g., audible performance alerts, performance violations). In addition, the DAS recorded multi-channel H.264 compressed video/audio on a custom electronics package designed specifically for automotive use. Three external camera views included the forward roadway (camera positioned on the windshield just left of center), facing rearward down the driver-side adjacent lane, and facing rearward down the passenger-side adjacent lane. The internal view included a front view of the driver's head and shoulders, with the camera positioned on the windshield just left of center. Note that the video cameras on the DAS were used in the study to validate measures from the non-video based OBMS.

OBMS Description

The OBMS included a touch screen display that was mounted near the center of the dash to provide easy access for the driver. The touch screen display also contained a speaker, which was used to provide feedback to the driver through means of audible, in-cab verbal alerts including the following: "check your speed," "please fasten your seatbelt," and "aggressive driving." The OBMS received information from the vehicle CAN bus related to vehicle parameters, such as vehicle speed. As is commonplace with the configuration of most CMVs, the fleet's vehicles did not carry a factory-installed sensor for seatbelt status. Therefore, a closed-circuit sensor (magnetic reed switch) was installed on each driver-side seatbelt buckle and tongue. The audible alerts were only active during the intervention period of the study. During the baseline period, the audible alerts were silent, meaning that the drivers were not informed of any performance infractions. Likewise, the OBMS did not communicate directly with fleet managers in any way during the baseline period.

The speeding and seatbelt alerts had a grace period associated with them. This is a feature designed by the OBMS vendor. A record of the violation would not be made on the OBMS or reported for manager review unless the performance criteria were exceeded for 15 s after the first audible alert was provided to the driver. The purpose of this grace period was to provide an in-vehicle system that was acceptable to drivers and intended to work alongside drivers in real-time to teach correct driving behaviors—separating consequences based on drivers' intentional extended performance, especially on cruise control, versus occasional errant vehicle activities. The OBMS was configured to the following vehicle performance criteria:

- Speeding:
  - Vehicle speed less than the posted speed limit + 5 mph (8.0 km/h).
  - Posted speed limit determined by the OBMS vendor's proprietary Speed-by-Street® technology.
- Seatbelt:
  - Vehicle speed $<$ 5 mph (8.0 km/h), or
  - Vehicle speed $\geq$ 5 mph (8.0 km/h) and seatbelt is buckled.
- Aggressive Driving Factors (proprietary and unitless):
  - Hard Brake: +2
  - Hard Turn: +3

- Hard Bump: 0
- Hard Acceleration: +6

- Audio Setting (not adjustable):
  - 85 dB at 1 m.

Data Reduction

Each file recorded by the DAS was reviewed to verify that the consented participant was indeed operating the vehicle. Any files with drivers recorded who were not consented participants in the study were excluded from further reduction. A data quality control process was performed once data files were transferred to the database. A random sample of violations and non-violations was abstracted from the data collected.

RESULTS

The following summary focuses on the rate of speeding and seatbelt violations as measures of the effects of the OBMS on driving safety and the change in those rates from the baseline period to the intervention period. Additional measures were captured by the DAS through the OBMS and DAS sensors, but are beyond the scope of this report.

Participant Demographics

A total of 27 (2 female and 25 male) drivers were recruited over the 11-month data collection period. The research team collected baseline data from 25 drivers. Of these 25 drivers, 20 successfully completed their 2-month baseline condition, and 19 collected data in the intervention condition. Among these 19 drivers, 2 completed at least 2.5 months of the intervention condition and 15 successfully completed the full 4-month intervention condition. Driver attrition due to study methodology was limited to one driver. The remaining attrition was due to fleet contract changes, driver employment changes, or driver health issues.

The 19 drivers (1 female, 18 males) who completed the baseline condition and at least some of the intervention condition reported both personal demographics and work experience during the screening process. Drivers had an average height of 69.5 in. (SD = 2.6) and an average weight of 203.9 lbs. (SD =36.9). Drivers reported working an average of 11.5 hours per shift (SD = 1.1) and 58.1 hours per week (SD = 13.6). They reported driving approximately 570.9 miles per shift on average (SD = 79.7). Among the 19 drivers, age and total years of experience driving were collected for 15 drivers. Among those 15 drivers, the average age was 52.53 years (SD = 8.03) and the average number of years of CDL driving experience was 21.33 (SD = 11.27).

Naturalistic Data Summary

In all, the research team collected 1,450,459 mi (2,334,289 km) of on-road data over a calendar period of approximately 11 months. The collected data were filtered to contain only consented drivers who had completed a collection of baseline and sufficient intervention data. The total collection that remained across baseline and intervention periods of 17 drivers was 1,196,146 mi (1,925,011 km).

OBMS Accuracy Assessment

Data reduction was performed to identify the accuracy of OBMS violations in terms of driver performance violations during the intervention period. The violations that the OBMS reported were speeding, not wearing a seatbelt, and aggressive driving. Violations captured by the OBMS, such as “speeding” for example, were available in a database variable called “violations” received by the DAS from the OBMS in-vehicle auxiliary data port. Only speeding and seatbelt violations will be discussed in the following OBMS accuracy results. In contrast, speeding and seatbelt non-violations were not obtained by the OBMS system record; rather they were identified by a randomly sampled drive file.

The number of aggressive driving violations that occurred, or captured, in the collection was very low. During the approximately 1.2 million miles of driving data collected, only 30 distinct aggressive driving violations were recorded by the DAS from the OBMS. Therefore, it was concluded that there was insufficient data upon which to establish an accuracy assessment compared to experimental instrumentation of accelerometers.

Speeding Violation and Non-Violation Accuracy

Speeding violations were validated by observation of posted speed signs on synchronous video captured by the DAS through the forward-facing camera near the event timeframe. Non-typical road scenarios, such as construction zones, that would make the posted speed data unreliable were not included in the accuracy assessment. Posted speed signs were observed in both the U.S. and Canada; posted speed signs from Canada were converted to miles per hour (mph) for the test. Reductionists also made note of signs that displayed truck speed limits that varied from speed limits for light vehicles.

Of the 689 sampled speeding violations, 593 (86.07%) were issued correctly (speeding observed, violation recorded). The remaining 96 (13.93%) were issued incorrectly (no speeding observed, violation recorded). The 95% confidence interval for the speeding correct violation rate was [83.48%, 88.65%]. The distribution of speed in the violation sample is displayed in Figure 1. A large proportion (83.0%) of speeding violations occurred between 60 and 85 mph. The speed distribution for all sampled speeding violations ranged from 30.5 mph (49.1 km/h) to 84.0 mph (135.2 km/h).

The non-violation sample used to evaluate speeding system accuracy included 701 non-violation periods. Speeding non-violations included 674 (96.15%) correct non-violations (no speeding observed, no violation recorded) and 27 (3.85%) incorrect non-violations (speeding observed, no violation recorded). The 95% confidence interval for the speeding correct non-violation rate was [94.72%, 97.57%]. The speed during non-violations ranged from about 25 mph (40.2 km/h) to 77 mph (123.9 km/h), with the majority (77.2%) of non-violations falling in the 60 to 70 mph (69.5 to 112.7 km/h) range.

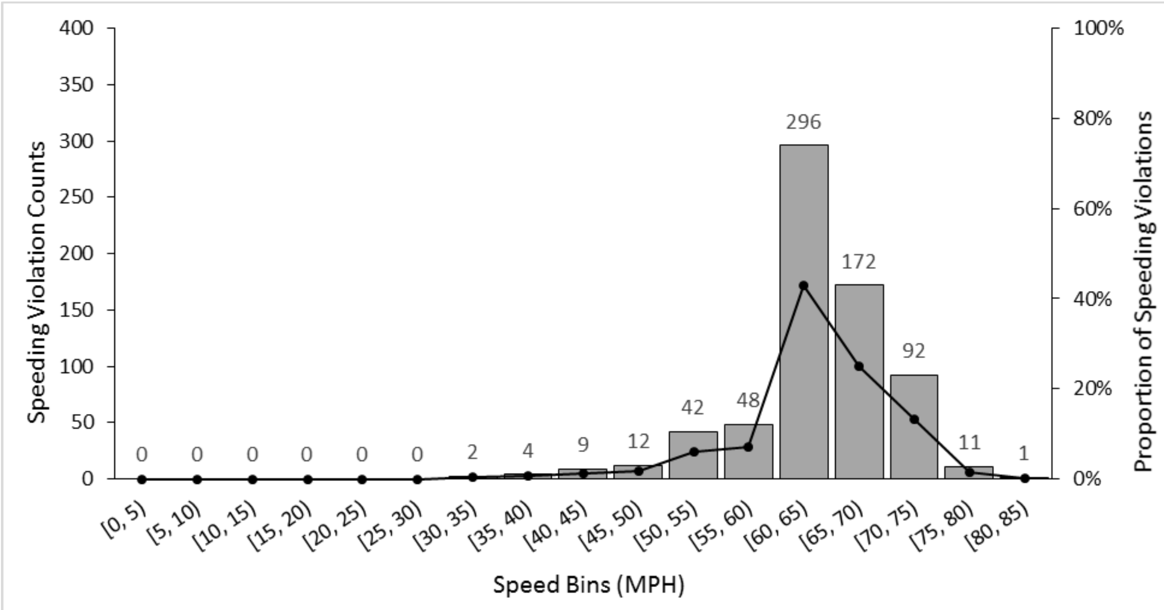

FIGURE 1 Distribution of speed in speeding violation sample

Seatbelt Violation and Non-Violation Accuracy

Seatbelt violations were validated on synchronous video captured by the DAS through a driver-facing camera at the event timeframe. Data reductionists made note if the vehicle was located in a parking lot during the seatbelt violation, and recorded whether the seatbelt appeared latched or not. The OBMS relied on a magnetic switch mounted to the buckle and tongue to determine if the seatbelt was being worn. Reductionists also noted when the seatbelt was not properly worn over the left shoulder in the event that the driver might be attempting to cheat the OBMS by sitting on the belt or wearing it under the shoulder while latched.

All 358 sampled seatbelt violations were correctly issued (seatbelt not buckled properly, violation recorded). The 95% confidence interval for the seatbelt correct violation rate was [99.86%, 100.00%]. Of the 358 sampled seatbelt violations, 303 or 84.6% occurred while driving in parking lots. The majority of seatbelt violations (93.3%) occurred while driving under 15 mph (24.1 km/h). The speed distribution for all sampled seatbelt violations ranged from 1.6 mph (2.6 km/h) to just over 68 mph (109.4 km/h).

The non-violation sample used to evaluate seatbelt violations included 449 non-violation periods, all of which were correct (all observations showed drivers wearing seatbelts). The 95% confidence interval for the seatbelt correct non-violation rate was [99.89%, 100.00%]. The non-violation sample included 24 (5.3%) observations in parking lots. The speed during non-violations ranged from just over 5 mph (8.0 km/h) to about 73 mph (117.5 km/h), with the majority of non-violations falling in the 65 to 70 mph (104.7 to 112.7 km/h) range.

As noted above, the research team also observed if drivers were trying to cheat the OBMS by latching the seatbelt buckle and sitting on the shoulder belt, lap belt, or both. Across the 449 non-violation periods sampled, only 33 (7.3%) were observed to have some deficiency in proper wearing of the belt across the lap and left shoulder (categorized as “loose shoulder belt”).

Safety Evaluation

Avoiding excessive speeding is a common measure of safe driving behavior. As noted at the beginning of this paper, of the CMV crashes identified by the Large Truck Crash Causation Study as resulting from driver error, 38% were attributed to decision errors such as exceeding safe speed (*3*). The OBMS being evaluated provides a means to warn drivers when the vehicle speed has exceeded 5 mph (8.0 km/h) or more above the posted speed limit. The OBMS system's Speed-by-Street® maps relied on preset posted speed limit references for the specific road being traveled and compared it to the real-time vehicle CAN bus reported speed.

The OBMS provided feedback to the driver when the seatbelt was not latched and when the vehicle was traveling above a fleet-configurable speed (in this case 5 mph [8.0 km/h]). As discussed in the results of the accuracy evaluation, the number of aggressive driving violations that occurred for all drivers was very low across the entire collection. Therefore, the aggressive driving violations could not be applied as a measure of safe driving behavior.

In both cases, speeding and seatbelt alerts issued an audible verbal message to drivers to check their speed or fasten their seatbelt. This initial audible alert was repeated every 10 s after the criterion were exceeded and continued until the criteria had been satisfied (e.g., vehicle speed was reduced below the referenced posted speed limit plus 5 mph [8.0 km/h] or seatbelt was buckled). If the driver failed to comply within 15 s, the OBMS recorded a violation that was communicated to the OBMS database and the fleet manager. For this study's purposes, the drivers only received audible alerts during the intervention period.

Speeding Activity

To validate the occurrence of a speeding violation, the researchers sampled and reviewed the video data recorded by the DAS prior to the violation in order to determine whether the posted speed limit on the road being traveled matched the OBMS's referenced speed limit. According to the sample averaged across all vehicles, the OBMS was 86% accurate at reporting speeding status during intervention. Therefore, 14% of the time, according to the sample, the OBMS reported that drivers were speeding when they were not.

Rates of speeding violations per 1,000 miles driven were calculated for each driver for baseline and intervention periods. Drivers averaged 29.01 violations per 1,000 miles in the baseline period (SD = 17.32) and 14.65 violations per 1,000 miles in the intervention period (SD = 13.11). Of the 17 drivers with speeding violation data, 14 (82.35%) drivers had a decreased speeding violation rate in the intervention period. The other three drivers (17.65%) had an increased speeding violation rate in the intervention period. The average difference in speeding violation rates (intervention − baseline) was 14.36 fewer violations per 1,000 miles (SD = 14.00) during the intervention period. A paired, one-sided t-test of the speeding violation rate differences (intervention − baseline) showed a statistically significant decrease ($t = -4.23$, $df = 16$, $p = 0.0003$).

The speeding violation rate per 1,000 miles was calculated for each driver, combined across the baseline period, and split between 2-week windows during the intervention period. Figure 2 shows the average speeding violation rate per 1,000 miles over time. Not every driver had data for all 2-week windows due to time off from driving or dropping out of the study. There was a sharp decrease in the average speeding violation rate from the baseline period to the first 2 weeks of the intervention period (from 29.01 to 18.37, a 37% decrease in speeding violations per 1,000 miles; 17 drivers were in each of the comparison periods).

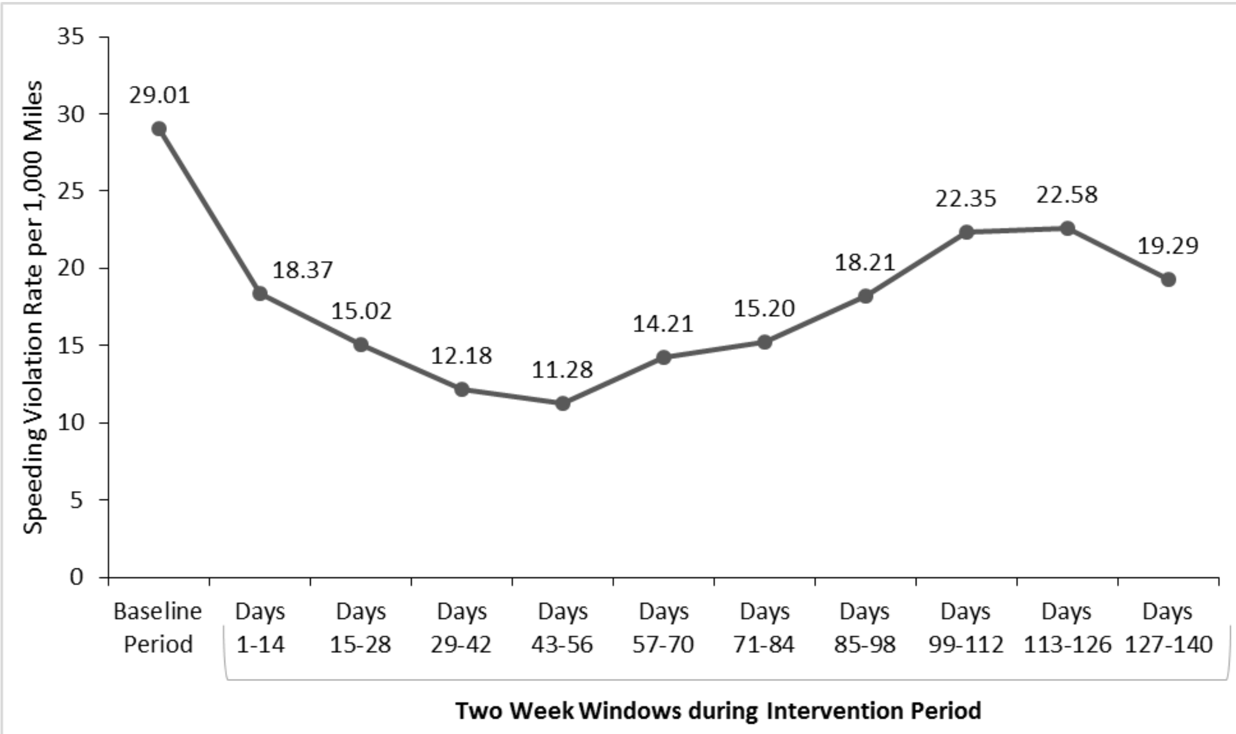

FIGURE 2 Speeding violation rate per 1,000 miles over time in study (baseline period and every 2 weeks of intervention period)

The speeding violation rate continued to decrease until the fourth 2-week window (days 43–56). However, from days 57 through 126, the speeding violation rate increased, although it remained lower than the baseline speeding violation rate. The ninth 2-week window (days 113–126) had the highest speeding violation rate during intervention (22.58 speeding violations per 1,000 miles; seven drivers with data for this window). However, a Wilcoxon Signed Rank test of the differences in baseline and the ninth 2-week window speeding violation rates was not significant, thus indicating no difference in the medians of speeding violation rates for drivers active in the ninth 2-week window compared to their baseline rates ($W = 10.0$, $p = 0.1094$).

Seatbelt Usage

To validate the occurrence of a seatbelt violation, the researchers sampled and reviewed the video data captured by the DAS during the violation to confirm whether the driver was or was not wearing the seatbelt. The OBMS's level of accuracy for the seatbelt latched and unlatched status during intervention was very high: 100% as sampled. Therefore, the seatbelt usage trends from baseline to intervention periods below can be understood to represent scenarios where the record of the seatbelt latched status was highly consistent with the driver's state of seatbelt usage.

Rates of seatbelt violations per 1,000 miles driven were calculated for each driver, for baseline and intervention periods. Drivers averaged 11.10 violations per 1,000 miles in the baseline period (SD

= 5.44) and 3.41 violations per 1,000 miles in the intervention period (SD = 3.92). Every driver had a decreased seatbelt violation rate in the intervention period. The average difference in seatbelt violation rates (intervention − baseline) was 7.69 fewer violations per 1,000 miles (SD = 5.12) in the intervention period. A paired t-test of the seatbelt violation rate differences (intervention − baseline) showed a statistically significant decrease ($t = –6.19$, $df = 16$, $p < 0.0001$).

Similar to the speeding rate, the seatbelt violation rate per 1,000 miles was calculated for each driver, combined across the baseline period, and split between 2-week windows during the intervention period. Again, not every driver had data for all 2-week windows due to time off from driving or dropping out of the study. Figure 3 shows the average seatbelt violation rate per 1,000 miles over time. There was a sharp decrease in the average seatbelt violation rate from the baseline period to the first 2 weeks of the intervention (from 11.10 to 4.88, a 56% decrease in seatbelt violations per 1,000 miles; 17 drivers in each of the comparison periods). A Wilcoxon Signed Rank test of the differences indicates a significantly lower median of seatbelt violations in the first 2 weeks of the intervention than the baseline period ($W = 74.5$, $p < 0.0001$). The rate of seatbelt violations during all 2-week windows of the intervention period remained significantly below the violation rate during the baseline period.

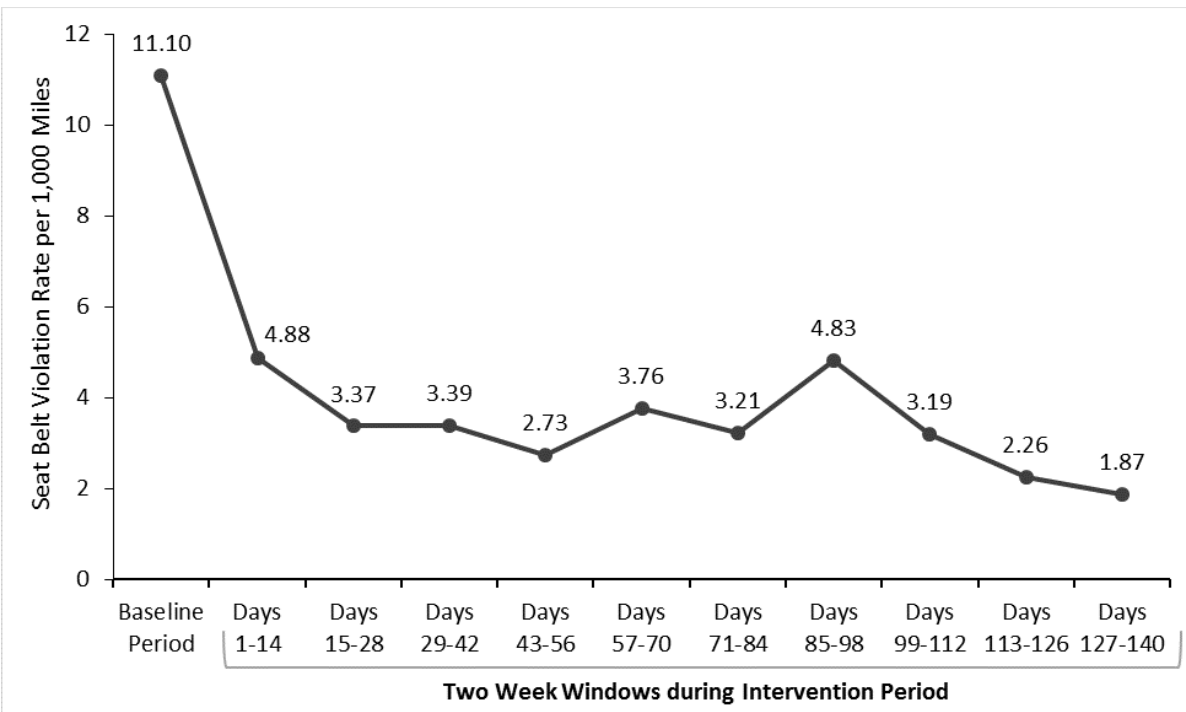

FIGURE 3 Seatbelt violation rate per 1,000 miles over time in study (baseline period and every 2 weeks of intervention period)

CONCLUSIONS

The field study indicated that the non-video-based OBMS performed reliably and had positive effects on driver performance. Field testing demonstrated that the OBMS speed monitoring correctly identified when CMVs were speeding 86% of the time on average. The OBMS seatbelt monitoring correctly identified when the seatbelt was unlatched 100% of the time. Interestingly, the majority of seatbelt violations occurred in parking lots (85%) and at speeds below 15 mph

(24.1 km/h; 93%). Sampled checks of seatbelt worn status confirmed that drivers did not attempt to circumvent the buckle sensor by sitting on the belt, although some occurrence of loose wear was observed.

A significant decrease in speeding violations was observed after the OBMS was activated for drivers in the intervention period. The rate of speeding violations per 1,000 miles, averaged across all drivers, was significantly reduced (37%) from baseline to the first 2-week intervention period. Additionally, a significant improvement in seatbelt use was observed after the OBMS was activated. The rate of seatbelt violations was significantly reduced (56%) from baseline to the first 2-week intervention period and remained at the reduced rate throughout the whole intervention period.

The notable increase in speeding violations, or return to baseline-similar performance levels, during the latter half of the intervention period is not uncommon among studies of monitored driver performance *(1)*. The current study has demonstrated that the commercial vehicle fleet made significant improvement in their speeding activities over the first 2 months. However, the fleet as a whole allowed their performance to degrade over the last 2 months. One implication of the higher rate of false alarms among the speeding violations may be that that drivers lost trust in the system's speeding alerts due to false alarms. (The cause of the speeding violation false alarms was found to be an inaccurate or outdated preset speed limit on OBMS speed zone maps compared to posted speed signs as validated by manual reduction of DAS-recorded video.) This is especially noteworthy, since the change in performance indicates that drivers chose to ignore repeated audible speeding alerts.

The number of OBMS aggressive driving violations collected was very low, and no hard acceleration violations were recorded. Additional accelerometry equipment was installed as part of the DAS on the participating vehicles, and the minimum, maximum, and mean g-forces of accelerometry were collected *post-hoc* at the point at which the aggressive driving violations occurred. Although the number of violations was too low to consider in the analysis, the characteristic g-force values that were measured on the DASs near OBMS aggressive driving violations are provided for future reference in Table 1.

TABLE 1 Vehicle g-Forces Summarized by Aggressive Violation Type

Violation Type	**Mean g-Force**	**Min g-Force**	**Max g-Force**
Hard Brake (dvX) [n = 11]	0.53	0.45	0.62
Hard Turn (dvY) [n = 18]	0.43	0.40	0.61
Hard Bump (dvZ) [n = 1]	NA	0.37	0.37

RECOMMENDATIONS

The evaluation of this specific OBMS provides some valuable guidance for both system providers and CMV fleets. Based on the results of this field test, opportunities for improvement, including regular audits of metrics and specific configurations for truck speeds, became apparent. The application of OBMSs may provide a useful resource for fleets desiring to improve safe-driving performance, as clearly demonstrated in this study by the success of seatbelt sensors to improve seatbelt use compliance rates. Fleets should consider their specific application needs when configuring OBMSs, and remain conscious that occasional inconsistencies will exist in the systems and allowances should be made for drivers to provide feedback to managers regarding system performance.

For system providers, to better understand the speed inconsistencies observed, future analysis of the entire data set, rather than the smaller—though substantial and driver-proportional—subset that was used in this study, is recommended. An important finding was that the fleet, as a whole, returned to baseline performance levels of speeding violations after 2 months of intervention. This may have been due to lack of accountability (i.e., "coaching") by fleet management or due to a lack of trust in the speeding alerts provided by the OBMS.

Future OBMS evaluation studies should capture fleet management feedback, which was not captured during the current study. Horrey et al. note the importance of OBMS studies to track organizational factors *(1)*. Future studies might recruit fleet managers as participants to allow for careful tracking of their weekly feedback activities. Better understanding of how the fleet managers use the OBMS data might provide insight into successes and shortcomings experienced in rolling out the program.

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