Evaluating a Real-time Invehicle Driver Monitoring and Auditory Feedback Device for Improving Fleet Driver Performance

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Abstract
Objective: To evaluate the use of a real-time driver monitoring and feedback device for improving driver safety performance in an ambulance transport setting.

Methods: Implementation of an aftermarket onboard real-time driver monitoring and auditory feedback device in the setting of two ambulance services was performed. System wide data was collected pertaining to driver performance, vehicle parameters and safety behaviours for each service during the pre-implementation and implementation period and subsequent fully implemented monitoring period. The data were captured every second, collected daily via infrared download and analyzed. System comparisons were performed.

Conclusions: Both services demonstrated system wide major and sustained improvements in driver behaviour, safety performance and safety proxies over 18-40 months, with a 1,000 fold sustained improvement in distance travelled without breach of safety performance thresholds (speed, torque, seat belt use), a reduction in crash frequency and severity, and improved emergency response times. Determining a baseline profile of transportation safety challenges and system wide safety hazards for each service is not yet well understood, limiting comparative system performance analysis. There is a need for categorization of ambulance crash severity, and for determining risk exposure rates for each driver. Safety researchers, emergency medical service providers and fleet managers should collaborate and consider use of these devices for both enhancing driver safety performance, and augmenting system wide transportation data capture. A technology based systems safety approach such as invehicle real-time feedback devices has been demonstrated to be highly effective. Applications for these devices should be considered for high risk drivers (ie. adolescents) and other vehicle fleets.

Keywords
Driver feedback technology, driver behaviour modification, in-vehicle monitor, in-vehicle telematics

Introduction
Ambulance transport safety is a complex issue [1,2,3,4]. Whilst there is a clear need for the ambulance vehicle itself to be safe and provide effective occupant protection [5,6,7,8,9], USA studies have identified that the majority of ambulance crash fatalities are outside of the ambulance vehicle, in a vehicle or pedestrian struck [10,11,12,13,14,15]. Ambulance vehicles have been identified in the USA to be one of the most lethal vehicles on the road, both per vehicle and per mile travelled [16,17,18]. Addressing vehicle operations policy to minimize the use of hazardous vehicle operations practice is an important priority. Whilst it is clear that an ambulance is an emergency vehicle, the frequency of its use being in a life threatening emergency is low, less than 3 percent of ambulance runs are described to be a critical or life threatening emergency [19]. Also, a cohort of those operating ambulance vehicles are younger males, EMTs have been demonstrated to have a higher risk of crashing their ambulance if they are under age 25, similar to the general population of drivers [20]. This study evaluates the implementation of a real-time in-vehicle driver monitoring and auditory feedback device for improving ambulance fleet driver performance [21,22,23].

The device evaluated was implemented in two USA ambulance services, of similar mix of urban, suburban and rural transport though overall size of the services differed (Table 1). In both settings the device was implemented in a step wise graduated manner as described in the methodology and its implementation monitored over a three year period in Site A and an 18 month period in Site B. This study is a comparative assessment of the performance of these devices as implemented in these two services. Preliminary report of this data is published by the author for Site A and Site B respectively [22,23].
Methodology

Implementation of an aftermarket onboard real-time driver monitoring and auditory feedback device in the setting of two ambulance services was performed, and the outcomes compared. The devices used was an electronic in vehicle monitoring device that provided immediate real time auditory alerts to the driver for reaching a hazard threshold, and then a penalty tone should that warning not be heeded and responded to. Each vehicle in the fleets was fitted with this device. System wide data was collected pertaining to driver performance, vehicle parameters and safety behaviours for each service during the pre-implementation phase I and subsequent phase II and III. The data were captured every second, collected daily via infrared download and analyzed.

Invehicle Computer System Study Device Overview – The onboard computer system monitors a number of parameters every second (see table 2) and provides real time auditory feedback to the driver by way of different tones. The parameters monitored include: vehicle speed (against user set limits – both hot & cold), hard acceleration/braking, cornering velocity and g-forces, use of emergency lights and sirens, use of front seat belts, turn signals, parking brake and back up spotters. Each driver has individual key “fob”. The key fob is a simple device, which must be keyed into a special contact lock on the vehicle dashboard at the time of the vehicles ignition, and thus identifies the driver of that vehicle. The computer system provides an audible real time feedback to the driver, by a system of warning growls and then penalty tones for when the set parameters are approached and exceeded (Table 2.). The onboard computer continuously records penalty counts when drivers exceed certain set parameters. The penalty count data recorded by the onboard computer for exceeding these parameters, are stored on the on-board computer and downloaded automatically to a base station on a daily basis for analysis and detailed electronic reports are generated. Management tracks trends and individuals. The device can be configured to alert management as well as the driver in real time via a cellular network. This feature was not enabled in either site in this study.

Results

Site A had about twice as many vehicles deployed and 4 times the distance travelled over all, so each vehicle deployed travelled twice the number of miles in Site A than Site B. Of interest, Site B had a longer mean response time. (Tale 1)

<table>
<thead>
<tr>
<th>Population Served</th>
<th>Site A: 500,000 people in Little Rock area, Arkansas</th>
<th>Site B: Serves The Lehigh Valley area, Pennsylvania</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ambulance Units Deployed</td>
<td>29 units daily</td>
<td>13 units daily</td>
</tr>
<tr>
<td>Ambulance calls</td>
<td>58,000 calls per year</td>
<td>34,000 calls per year</td>
</tr>
<tr>
<td>Service Area</td>
<td>2,400 square mile service area</td>
<td>~1,000 square mile service area</td>
</tr>
<tr>
<td>Operational Employees</td>
<td>195 full time / 75 part time uniformed employees</td>
<td>152 drivers (including part time and volunteer)</td>
</tr>
<tr>
<td>Ambulance Miles Travelled</td>
<td>1.9 million miles annually</td>
<td>450,000 miles annually</td>
</tr>
<tr>
<td>Mean response time</td>
<td>6 minutes</td>
<td>11 minutes</td>
</tr>
</tbody>
</table>

Table 1: Profiles of Site A and Site B

Implementation Phase - Both sites used a similar 3 phase graduated approach in implementing the device. Initially for Phase I blind data was captured to identify baseline performance with no tones and no ID capture, followed by Phase II with tones implemented but no ID capture, then fully operational in Phase III. Site B had an extended Phase II to ensure outreach to a cohort of part time and volunteer drivers (Table 2)
Phase I -
Blind data - no tones, no ID capture:

Site B: 11/2004 to 5/2005

Phase II -
Warning and penalty tones only:

Site B: 5/2005 to 7/2006

Phase III -
Fully operational:

Site B: 7/2006 to 9/2006

Table 2: Implementation Phase

<table>
<thead>
<tr>
<th>Speed</th>
<th>Site A</th>
<th>Site B</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low Speed (LSCOUNT)</td>
<td>15 second warning period - 74 / 78 mph</td>
<td>10 second warning period - 73 / 78 mph</td>
</tr>
<tr>
<td>High Speed (HSCOUNT)</td>
<td>- 84 / 88 mph</td>
<td>- &gt;79 mph</td>
</tr>
<tr>
<td>Cornering</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Low Over Force (LFCOUNT)</td>
<td>warning at 25% - 39%</td>
<td>warning at 25% - 38%</td>
</tr>
<tr>
<td>High Over Force (HFCOUNT)</td>
<td>- 55%</td>
<td>- 48%</td>
</tr>
<tr>
<td>Reverse Count (RVCOUNT)</td>
<td>- 1 count for each time the vehicle is placed in reverse without the reverse spotting switch being engaged</td>
<td>- 1 count for each time the vehicle is placed in reverse without the reverse spotting switch being engaged</td>
</tr>
<tr>
<td>Seat Belt Distance (SBCOUNT)</td>
<td>- 2/10ths mile (0.2 mile)</td>
<td>- 1/10ths mile (0.1 mile)</td>
</tr>
</tbody>
</table>

LSCOUNT = Low Speed Count (non emergency) - If the vehicle exceeds the numerator MPH, the driver receives warning beeps warning them to reduce their speed. If they fail to do so, one low speed count is recorded for each second the vehicle is between numerator and denominator MPH values.

HSCOUNT = High Over speed Count - the system records an instant high over speed count every time the vehicle is driven in the range described in Site A with warning period as described, or in excess of 79 MPH in site B.

LFCOUNT = Low Over force Count - total number of seconds the vehicle experienced a force greater than the Low Over force setting which varies from class of vehicle to class of vehicle.

HFCOUNT = High Over force Count - total number of seconds the vehicle experienced a force greater than the High Over force setting, which varies from class of vehicle to class of vehicle.

RVCOUNT = Unsafe Reverse Counts - One count is registered for every time a driver puts the truck in reverse without a spotter pressing the inside or outside spotter switch.

SBCOUNT = Seatbelt Counts - one count is registered for each fraction of a mile that the driver drives the vehicle without buckling the seatbelt.

Table 3: Onboard Computer Device Settings used in this study

The speed tolerances and seat belt tolerances are more stringent in Site B. The speed warning period is 30% shorter, and the seat belt tolerance is 50% of the tolerance distance. (Table 3.)

The overspeed and seat belt data recorded for site A (Figure 1. i and ii), depicts a sustained and quite profound improvement in driver safety proxies and performance. This is in a setting of no additional in-service training, no time out in drivers education classes. The outcome improvements were sustained over the period from July 2003 to July 2006 with one thousand fold improvement in these safety proxies. Similar results were seen in the Site B data (Table 4), though the duration of the Phase III period of the study was much briefer, as an extended Phase II had been implemented due to the unique mix of providers at that service with part-timers and volunteers with low frequency rates for being in the driver role.
**Figure 1:** Individual plots of the data are represented for Site A: i. Overspeed, ii. Seat belt violation

i. Overspeed violations/month

ii. Seat belt violations/month
<table>
<thead>
<tr>
<th></th>
<th>Phase I</th>
<th>Phase II</th>
<th>Phase III</th>
</tr>
</thead>
<tbody>
<tr>
<td>Distance (miles)</td>
<td>193,210</td>
<td>682,320</td>
<td>75,957</td>
</tr>
<tr>
<td>LSCOUNT [LSCOUNT/mile]</td>
<td>89,259 [2.16]</td>
<td>100,195 [0.5]</td>
<td>96 [0.001]</td>
</tr>
<tr>
<td>HSCOUNT [HSCOUNT/mile]</td>
<td>12,936 [14.94]</td>
<td>14,448 [0.02]</td>
<td>2 [0.00003]</td>
</tr>
<tr>
<td>LFCOND [LFCOND/mile]</td>
<td>37,347 [0.19]</td>
<td>64,328 [0.09]</td>
<td>1,250 [0.02]</td>
</tr>
<tr>
<td>HFCOUNT [HFCOUNT/mile]</td>
<td>552 [0.003]</td>
<td>1,210 [0.002]</td>
<td>56 [0.001]</td>
</tr>
<tr>
<td>RVCOND [RVCOND/mile]</td>
<td>15,697 [12.31]</td>
<td>69,779 [0.10]</td>
<td>7,100 [0.09]</td>
</tr>
<tr>
<td>SBCOUNT [SBCOUNT/mile]</td>
<td>40,893 [4.72]</td>
<td>45,366 [0.07]</td>
<td>90 [0.001]</td>
</tr>
</tbody>
</table>

LSCOUNT = Low Speed Count (non emergency); HSCOUNT = High Over speed Count; LFCOND = Low Over force Count; HFCOUNT = High Over force Count; RVCOND = Unsafe Reverse Counts; SBCOUNT = Seatbelt Counts

Table 4: Summary table of performance over each Phase for Site B

Response times - At Site A, the total volume of calls increased during the study period from ~93,000 miles/month to ~113,000 miles/month, whilst the vehicle and personnel resources remained constant. It was anticipated that under these circumstances that the response times would substantially increase, however the response times remained constant at 6 minutes, which suggests an actual improvement in response time performance with the system implemented. In site B there was no increase in average response times during the study period- 11:14 minutes in 2004, 10:36 in 2005, and 10:46 minutes in 2006, this data suggests a moderate overall improvement in response times during the study period.

Crash Rates - Overall, there were fewer crashes and less severe crashes than over the preceding similar time periods. At site A, there were no serious crashes reported during the study period. There was one unavoidable vehicle crash due to a bridge obstruction that required evasive action. At Site B, there were 19 vehicle incidents in 2004, 11 in 2005 and no major vehicle crash during the fully implemented phase of the study period. There was sustained improvement in safety proxies over the Phase II and III periods in both services, with no in-service or retraining after the initial introduction period. There were cost savings to both services in having a decreased number of serious crashes, decreased vehicle damage, and a decrease in the required investigations of those events, with resultant insurance savings also.

Discussion

This study demonstrated similar very effective outcomes for each of these services, in the implementation of the real time auditory in vehicle feedback device. As has been demonstrated with historical data of ambulances having a longstanding poor transport safety record, and that despite changes to operational policy, it does appear that relying on operational policies alone to monitor and manage fleet safety performance has not been effective in ambulance transport in the USA. The implementation of this device in the two sites evaluated in this study demonstrated impressive and sustained improvements in all safety proxies, even given the slight differences in both the size and implementation nature and period of these devices. A major challenge in conducting this comparison is the difficulty in determining a baseline profile of transportation safety challenges and system wide safety hazards for EMS services. Measuring these parameters for each service is not yet well understood, limiting detailed comparative system performance analysis.

Whilst there are performance benchmarks that give some functional measure of the congestion and severity of patient load in the setting of the hospital emergency departments, there exists no such functional measure for congestion and severity of patient load in the pre-hospital or ambulance setting. It
maybe that one system may have had a greater level of hazard and risk, and yet had already optimized that risk, and hence there was little scope for substantial gains in safety improvement, and that another system may have had not optimized their safety performance, thus the implementation of a fleet safety device and initiative would provide a major system performance advantage.

The gold standard in true effectiveness is a decrease in both crash rate and near miss rate and a decreased injury rate. It does appear that both these systems had relatively safe transport performance even prior to implementation with few major or serious crashes. There may well be a bias that a system that is safety conscious is more likely to make an investment in a safety system such as this than a less safety conscious EMS system. Thus it is possible that if it were implemented into an EMS system with a poor safety record, that the degree of performance improvement may be higher. In other regions in the USA where this technology has been implemented there are reports of high rates of crash reduction (up to 90% reduction in crashes when compared to historical controls).

However that being stated, both systems successfully implemented this technology, and demonstrated quite dramatic and sustained improvements in safety proxies and performance. This sustained effectiveness is particularly the case in system A, where data capture in the fully implemented system has been in place for an extended period. These systems clearly appear to have markedly improved driver performance and behaviour system wide, and though not represented in this paper, individual driver performance captured by these systems also demonstrates that clearly.

This raises the issue of such devices being regarded as ‘Driver training tools’ rather than being solely regarded as safety monitoring and feedback devices.

**Limitations**

There are a number of limitations in this study beyond the challenges of determining the system load. Firstly, these systems require a commitment at management level to properly implement and manage the system and the data. These two examples were of services where the system was introduced in a horizontal manner with active engagement of all levels of fleet staff, and explanation of the purpose and benefit of these devices. There were also good performance rewards offered in both systems, with the focus more on rewarding safety than being punitive.

Additionally, there are a number of specific limitations to this study, asides from the variations in the sites studied, and the manner and duration in which the devices were implemented. There are also variations in the manner in which response times are calculated within an EMS system and furthermore, there maybe some differences in safety policy and procedure between the sites.

Also, given that the data exists to demonstrate that younger drivers were more at risk of adverse transport events this study did not include an analysis of the driver risk at each site, by age or by driving record. A logistic regression including data on driver age, history, congestion of the EMS system, pressure to perform and meet targets may well add valuable definition to the quality of the data. Also, the devices can be ‘tricked’, a seat belt buckled behind the driver, accelerating to run the red light to avoid a hard braking penalty. The frequency of these behaviours at both sites was not measured.

There is a role for detailed economic analysis of the implementation of these systems, to identify, costs savings in maintenance, fuel efficiency, overall cost benefit of fewer and less severe crashes. Some preliminary studies have demonstrated that in maintenance alone these devices pay for themselves in less than 6 months, not including fuel savings or cost savings due to having a safer system.

**Conclusions**

The evaluation of the implementation of real-time driver monitoring and feedback device for improving driver safety performance in an ambulance transport setting demonstrated that both services demonstrated system wide major and sustained improvements in driver behaviour, safety performance and, with a 1,000 fold sustained improvement in safety proxies, a reduction in crash frequency and severity, and improved emergency response times. Determining a baseline profile of transportation safety challenges and system
wide safety hazards is not yet well understood, limiting comparative system performance analysis. There is a need for categorization of ambulance crash severity, and for determining transportation risk exposure rates for each environment and for each driver. A technology based systems safety approach such as this in-vehicle real-time feedback device has been demonstrated to be highly effective in these ambulance services. Safety researchers, emergency medical service providers and fleet managers should collaborate to address the identified system limitations and ambulance services should consider use of these devices for both enhancing driver safety performance, and augmenting system wide transportation data capture. Applications for these devices should be considered for high risk drivers (ie. adolescents) and other vehicle fleets.

Acknowledgements

The data for this study was collected at two sites, Metro EMS in Little Rock Arkansas, and Cetronia Ambulance Service in Allentown Pennsylvania. The author gratefully acknowledges the contribution of John Swanston of Little Rock and Larry Wiersch and their colleagues for their assistance in collecting the original data and their input into the preparation of the initial manuscripts, and subsequent follow up data.

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