Improving highway safety through in-cab driver alerts

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Abstract

The growth of digital connectivity through V2X data platforms and exchanges means millions of trucks in North America are connected. Transportation agencies have an unprecedented opportunity to expand traditional highway safety programs into connected truck networks to refine their safety programs. These connected truck solutions support a variety of traveler information programs, allowing transportation agencies to reach millions of trucks and communicate in-cab safely – sending critical safety alerts directly to truck drivers approaching hazards on the roadway. This paper addresses a current problem with highway safety that cannot be solved with traditional traveler information methods: there are too many fatal crashes on our roadways. And it is too challenging to notify the right drivers, with the right message, at the right time to prevent them—a problem which is compounded by increasing freight volumes on roadways. After providing context on the history of traveler information systems (beginning with manual and infrastructure-dependent solutions) to identify where challenges currently exist, the paper explores opportunities presented by integrating agencies' safety programs into connected truck networks, with a focus on in-cab driver alert solutions currently available in the market. This research includes the potential benefits and return on investment for agencies as a result of participating in a connected truck safety program that sends real-time in-cab driver alerts, including the ability to assess driver behavior and safety program success through customizable data insights--a unique benefit for those who form part of a connected truck ecosystem.

Keywords

Connected, alerts, in-cab

The problem with highway safety: there are too many fatal crashes

The statistics paint a grim picture. In 2021, there were 5,601 fatalities involving heavy trucks—up by 13% over 2020. In conjunction with nearly 43,000 total motor vehicle fatalities, it marked the highest number since 2005 (1).

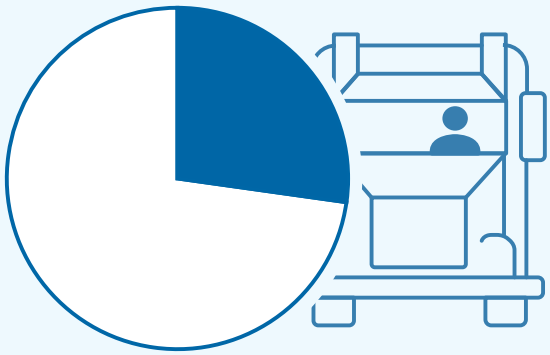
According to the National Highway Traffic Safety Administration (NHTSA), crashes on interstates represent nearly 30% of all collisions. Many are secondary incidents where a truck or car rear-ended a vehicle that was in a queue resulting from an initial crash (2). Highlighting the problem is a 2019 Pennsylvania Department of Transportation study which showed 32% of work zone crashes and 49% of secondary crashes occurred more than two miles back from the origin point of congestion. Additionally, 46% occurred over an hour later (3).

There is a saying that "speed kills," and it is true. A 2020 NHTSA study found that 28% of fatal crashes, 13% of injury crashes, and 10% of property-damage-only crashes were speeding-related (4).

These bleak statistics extend from commercial motor vehicles and passenger vehicles to first responders and other service vehicles. As detailed in the National Roadway Safety Strategy (NRSS), transportation incidents are the leading cause of death for tow truck drivers and the second leading cause of death for emergency medical technicians, paramedics, firefighters and police officers. The Department of Transportation estimates that each minute that a crash remains uncleared (including possible lane closures) presents a hazard. In this case, the chance that a secondary crash occurs raises by 2.8%. This poses a serious risk for passing vehicles, as well as increased danger for emergency and service personnel on the scene (5).

For commercial trucks, speed and collisions can be a deadly combination. Tractor-trailers can exceed 80,000 pounds in some states, and trucks traveling 65 miles per hour need twice the length to come to a stop as compared to a car—about two football fields (6). That is why slowing down in advance of congestion, a sudden slowdown or other hazards—including causes such as increased traffic volumes, construction work, or an emergency on the roadway—is so important.

Within work zones specifically, there is a known correlation between fatal crashes and commercial motor vehicles. In 2020, 208 out of 774 fatal crashes in work zones involved a commercial motor vehicle. On rural interstates, nearly 77% of fatal crashes involving a commercial motor vehicle in work zones were caused by a rear-end collision. Although this number has decreased since 2019 (when there were 252 commercial motor vehicle work zone crashes) Federal Highway Administration (FHWA) has acknowledged that there "has still been a clear upward trend over the past 10 years" (7).



In 2020, **208 out of 774** fatal crashes in work zones involved a commercial motor vehicle.

Figure 1 number of crashes involving commercial motor vehicles in work zones

In the years ahead, the number of trucks populating our roadways will only increase. Freight volume across the United States is expected to grow by 36% by 2031. This will only compound the problem of highway safety (8).

The goal: zero fatal crashes

Federal and state government agencies in the United States are aligned in their mission to reduce crashes, injuries, and fatalities along transportation routes. A notable example is the Federal Motor Carrier Safety Administration (FMCSA), a separate administration within the U.S. Department of Transportation (U.S. DOT), whose primary mission is "to reduce crashes, injuries and fatalities involving large trucks and buses." The FMCSA strategy to realize this safety mandate includes focus areas on "data-driven regulations that balance motor carrier…safety with efficiency" as well as safety information systems that focus on high-risk carriers (9).

The U.S. DOT has recently announced a call to action, "a responsibility to make our roadways safer for everyone" with the understanding that no single agency, organization, or roadway user can tackle this initiative alone. In alignment with the National Roadway Safety Strategy (NRSS), a variety of stakeholders and partners will need to come together to make the roads safer for everyone (10).

As detailed in the NRSS, to reach a goal of zero roadway fatalities, the U.S. DOT has shifted from a conventional safety approach to a "Safe System Approach" which acknowledges the presence of human mistakes and error, by seeking opportunities to design a redundant system to lessen the impacts of any mistakes and errors (11).

Focus area: *a safe system approach to reducing crashes involving commercial motor vehicles*

This paper applies the Safe System Approach to a commercial motor vehicle context, focusing on the potential for in-cab alerting solutions to positively affect human behavior. This study addresses how truck driver behavior is impacted from targeted in-cab safety messages, related to static road characteristics and dynamic conditions, and the resulting potential impacts that changed behaviors have on reducing the risk of crashes in hazardous conditions such as in congested areas, emergency response scenarios, work zones, and other custom alert zones.

Another notable principle within the NRSS' Safe System Approach is that "Safety is Proactive", which highlights the need for tools that can identify and mitigate safety hazards in the transportation system before an incident occurs. This principle underpins the goal of reducing crashes involving heavy trucks as proactive identification and dissemination of hazard data to truck drivers is essential to stopping crashes before they happen because of the extra time and distance needed for commercial motor vehicles to react.

Although access to and quality of traffic data has improved over the last few decades, there have been minimal viable studies on the impacts of transmitting safety-critical and real-time traffic data to commercial motor vehicles, inclusive of higher risk carriers, using connected truck networks. This paper has addressed this gap by identifying existing connected truck technologies that can be incorporated into agency safety programs, including assessing the results of recent pilot programs across the United States.

However, before reviewing opportunities to address the highway safety problem using connected truck networks, it is important to review a history of traveler information systems in North America to better understand the challenges with using traditional safety program technologies. After this historical review, this paper will investigate which advanced in-cab alerting technologies are available for implementation to improve agencies' safety program success.

The history: *traveler information systems*

Traveler information systems have evolved significantly over the last three decades. In the 1990s, these systems mainly transmitted information via location-specific road condition hotlines, variable message signs, radio, and television.

On July 21, 2000 a single traffic information telephone number (511) was designated for Intelligent Transportation System (ITS) traveler information to be made available across all states and local jurisdiction across the United States. Although 511 was a positive step in encouraging national implementation and

addressed the transportation community's requests for a nationwide traveler information telephone number, it presented a key challenge. Because states and local agencies were responsible for implementation, and were granted flexibility on service types and scheduling, there was a risk that the type, quality, and cost of services would be delivered inconsistently across a national scale (12).

By 2005, as detailed in a report prepared by the University of Utah, the four main traveler information technologies were Variable Message Signs (VMS), Highway Advisory Radio (HAR), the 511-phone system, and CommuterLink website. The objective of these technologies, as part of an overall transportation management program, was summarized in the report as:

"[Optimizing] the existing road network capacity by efficiently managing and controlling vehicles on the roadway. Drivers can use [Traveler Information Systems] to dynamically react to road conditions and thereby optimize the road network by changing their departure time, taking an alternative route or choosing a different travel mode. Pre-trip information, such as roadway conditions and route congestion, is available to motorists in Utah through online services (CommuterLink website) and telephone services (511). En-route information on incidents, roadway and environmental conditions, and alternative routes is available to the traveling public through Variable Message Signs (VMS) and Highway Advisory Radio (HAR)."

Although this report concluded that survey respondents viewed these technologies as useful, several shortcomings were identified. The report's recommendations included:

- Look for ways to better serve commercial vehicle drivers,
- Add more VMS destinations,
- Increase maintenance frequency for message boards to ensure current information and that board is operating correctly,
- Improve coverage for HAR and increase frequency of updates during peak periods, and
- Make 511 easier to navigate. (13)

And indeed, these traditional technologies continue to present similar challenges today, even with the public's support for implementation. In a study conducted by Michigan State University in 2021, public feedback expressed that drivers found significant value in safety messages, including those presented on Dynamic Message Signs (DMS). However, field studies on driver behavior often showed either limited or virtually no change in driver behavior after seeing safety messages on the DMS. One key exception being that safety messages targeting specific high-risk behaviors (such as speeding) did present a statistically significant reduction. In addition, the study acknowledged that there are limitations in assessing the

impacts of DMS messages, as the researchers could not confirm whether drivers saw and understood the messages and "extensive quality assurance efforts were required" to leverage the state's message data (14).

Fortunately, technologies have since evolved—from passive, widespread notifications to active, targeted notifications—to help address these challenges. In addition to being displayed on roadside infrastructure, notifications can now be disseminated across mobile applications and in-vehicle and in-cab devices, which have the ability to leverage connected vehicle networks for real-time and targeted alerting capabilities.

Figure 2 history of traffic information systems

The opportunity: *extend safety programs into truck cabs*

Today, there are about 12 million large trucks and buses operating on our roadways, delivering freight and using interstates.

Traveler Information Systems (TIS) were initially developed to get traffic information into the hands of the public – moving from phone lines to radio to roadside signs to websites, and most recently to apps inside vehicles. The trucking industry, however, carries greater risks and is more regulated. Truck crashes have higher injury and fatality rates along with the capacity to do greater damage and have more significant impacts on other traffic. While other apps target passenger vehicles and are not truck safe, there are current applications (such as Drivewyze) which can fill the gap by delivering vital information timed and tailored to truck drivers without requiring additional hardware or software in the vehicle or infrastructure at the roadside.

For a large truck, seconds matter. If a driver of a truck has advanced notice of an upcoming slowdown or congestion, it can make all the difference when it comes to highway safety. In addition, when trucks

slow down and other motorists see the truck's brake lights, they tend to behave the same. Since trucks ride higher off the ground, they act as a beacon of what is ahead.

State agencies now have the opportunity to expand their safety programs into trucks and provide truck drivers with in-cab alerts in advance of slowdowns and congestion thanks to unique partnerships between connected truck platforms and leading data providers in the transportation analytics and connected vehicle services space.

With advancements in data collection and analytics capabilities, leading data providers can use complex algorithms to analyze millions of anonymous connected vehicles traveling more than a billion miles daily in the United States. With access to this information, companies are now able to identify and monitor traffic at a granular and targeted level, which includes, but is not limited to, which traffic areas result in slowdowns. When this information is relayed from data providers to a connected truck platform, safety benefits for commercial motor vehicles can be realized. Drivewyze—which has a Smart Roadways safety alerts program integrated with nearly 3 million trucks—is one example of a connected truck platform currently available on the market. With this program, safety-critical alerts are simple and free for trucking fleets to enable on their always-on Electronic Logging Devices (ELDs). As telematic devices, these ELDs are able to record and transmit immense amounts of data across long distances, efficiently and accurately. This data not only helps agencies notify the right drivers of hazards, at the right times and locations, but also assess the resulting driver behavior and safety alert effectiveness. Examples of data records in ELDs which can help inform safety program design and decisions include real-time GPS tracking, miles traveled, fuel efficiency, and hazardous driving behavior such as accidents and hard braking.

Using in-cab alerts to protect drivers

By notifying drivers through ELD devices, alerts can be sent based on location, allowing agencies to target specific drivers who are approaching hazards on the roadway. Messages such as "Sudden Slowdown Ahead" and "Congestion Ahead" can be displayed on ELDs approximately 2 to 3 miles before the slowdown begins, giving truckers plenty of time to slow their speed. As an additional benefit, this notification approach eliminates the need for costly infrastructure as it involves using existing in-cab devices, with drivers who are already familiar with these types of applications and interfaces.

Not only are safety alerts programs already available for deployment in the market, but they have been tested and proven with positive results in multiple states, which will be explained later in this paper. The pilot studies presented in this paper are unique, as they not only involved distributing real-time alerts to targeted drivers, but also provided an opportunity for agencies to observe the resulting

driver behavior (such as route selection decisions and hard braking activities). These insights into driver behavior demonstrate the potential for these connected programs to extend beyond driver notification, to help agencies analyze the effectiveness of specific alerts, and in turn, make decisions and changes that improve the success of the overall alerts program.

Using in-cab alerts to protect first responders and other service vehicles

As mentioned previously in the problem statement of this paper, transportation incidents are the leading and second leading cause of death for tow operators and first responders (police officers and firefighters), respectively. To address this alarming statistic, the United States Department of Transportation has prioritized several key departmental actions that enable safer post-crash care. These actions involve advancing traffic incident management training and technologies that can help improve safety for motorists and first responders, including those on-scene at a crash (15).

Fortunately, recent technological advancements are now available to support these actions. With service vehicle data now available on various networks, combined with the ability notify vehicles directly of upcoming service vehicle locations and incidents through V2X means, first responder safety can be greatly improved.

As an example of current advancements within the connected truck space, connected truck platforms can leverage digital alerting platforms on emergency and service networks. Agencies can now provide alerts about safety vehicles and equipment on the roadways via these connected truck platforms. Maintenance, emergency response, and work zone events can often place vehicles and equipment in situations that can be hazardous to both workers and drivers. In-cab alerts provide messaging, such as "Emergency Vehicle Ahead, Please Slow Down and Move Over."

Customizing safety alerts for agency safety programs—including work zones

In addition to real-time alerts, states can expand their in-cab alert safety programs using customized and dynamic safety messaging. These can include known locations for crashes or jackknives involving heavy trucks, critical work zones, or other areas where added attention to speed is warranted. And with work zones accounting for up to 35% of congestion in rural areas, alerting drivers in advance of these areas can positively impact the overall success of the state's safety program.

North Carolina is one state making use of custom state alerts to improve their safety program, including in critical work zones. "We have taken advantage of the alerts in two ways," said Kelly Wells, traveler information engineer for the state's Department of Transportation.

"We have some very impactful interstate work zones in western North Carolina on I-40 near Tennessee. We used Drivewyze alerts to let trucks approaching the work zone know that once they got into the work zone there were no alternate routes. So we suggested a route they should take before they ever got to the work zone. The work zone queues wound up being less than we expected so this could mean that trucks heeded our alerts and took alternate routes around the work zone."

Wells said they also used the alerts to keep trucks from restricted routes. "We routinely get complaints about trucks on truck-restricted roads in western North Carolina," she said. "We asked Drivewyze to geo-fence the approaches to six of our most problematic locations. Since these alerts began in July (2022) more than 10,000 alerts have been issued and, to date, no alerted drivers have traveled on the restricted roads."

The results: in-cab alert pilot programs and their impacts on driver behavior

To study the effectiveness of an in-cab alert safety program, North Carolina, New Jersey, Ohio, Georgia, and the Pennsylvania Turnpike were the first states to partner with Drivewyze to pilot this technology, providing alerts covering more than 3,500 miles of the most-traveled freight corridors. The network is rapidly expanding as other states are completing pilot programs or due diligence on this technology.

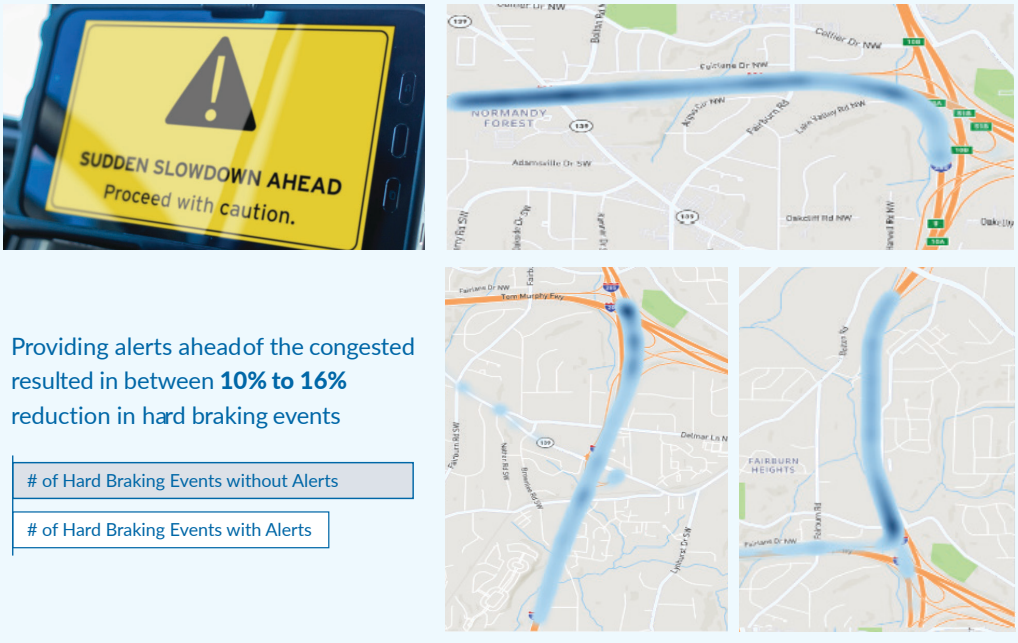


Figure 3 results of congestion alerts on reducing hard braking events

And the studies show that in-cab alerts have a significant impact. In North Carolina, analytics found that 70% of drivers that received an alert slowed down ahead of an incident. Speed was reduced, on average, by 11 miles per hour (compared to 2 miles per hour in a control group) ahead of a sudden slowdown. When coming upon a congested area, trucks with the alerts slowed by an average of 8 miles per hour (compared to 3 miles per hour with the control group).

In the Atlanta area, the Georgia Department of Transportation found that in-cab alerts had a significant impact on hard braking in eight of 10 sites identified in a pilot project. Some locations had hard braking reductions as high as 19%.

A study conducted in the summer of 2021—with a major national carrier, which has over 10,000 vehicles in its fleet —compared the behavior of drivers who received alerts, and those who did not. Not surprisingly, drivers that were shown alerts slowed down. They had fewer speeding incidents overall, and most importantly, had over a 50% reduction in excessive speeding (over 15 miles per hour).

Simply, these studies demonstrated that in-cab alerts help drivers slow their trucks down before it is too late (16). They make our roadways safer.

In-cab alerts make a difference

Here is what states have to say

Driver-direct technology can make roads safer for all and can make a difference for Departments of Transportation safety programs across the country.

North Carolina was the first state to use the Drivewyze Smart Roadways safety alerts program as part of pilot testing, which began with approximately 500 miles of roadway in 2021. Results prompted the state to expand this pilot initiative to cover over 5,000 miles of roadways with the alerts.

Wells said the state is committed to improving highway safety, and the willingness to use new technology. “[The safety alerts program] is a great way to use the technology of probe speed data that we have been using for over 14 years in a new application,” she said. “It allows us to put the slowdown information right into the truck, right at the point of need where they are traveling. The existing process of notifying drivers using Dynamic Message Signs requires humans to interact with the information which slows down the process. We also have only 300 Dynamic Message Signs even though we have over 5,000 miles of freeways in our state. There are lots of places where we don’t have these signs to communicate with drivers. “[The virtual safety alerts program] helps us overcome that gap in DMS coverage.”

According to Ben Lempke, assistant state ITS engineer for the Georgia Department of Transportation, safety on Georgia's roads is the highest priority for the Department of Transportation. "The state has worked toward zero traffic deaths for years," he said. "That's where driver alerts come in. We recognize real-time safety messaging as a key strategy to minimize crashes due to unexpected slowdowns. This messaging becomes even more critical when you factor in the additional stopping distance required for trucks and the seriousness of truck-involved crashes. Our partnership with the [connected truck platform] has been influential in our goal to deliver safer roadways for all travelers."

The Pennsylvania Turnpike has all 564 miles of its roadways covered with real-time, in-cab alerts. Said Craig Shuey, PA Turnpike Chief Operating Officer: "Unpredictability on the roadway causes downstream impacts that pose potential issues for truckers, dispatchers, shippers, and road management organizations. Our commercial trucking customers tell us it's imperative to be kept informed about hazards on the road ahead in the most distraction-free manner possible and alerted with enough time and detail to process and react efficiently and safely. This new alert system enables us to improve real-time roadway communications that also pay further dividends in improved safety."

Data to validate effectiveness and return-on-investment

There are current technologies available on the market which are designed to give a state agency complete control over the in-vehicle extension of their highway safety program. This includes analytics and reporting with key performance indicators to provide the necessary feedback to an agency to validate the impact of the program on driver behaviors like speeding and unsafe driving. Analytical results provide a data-driven proof of performance that agencies require to substantiate their investments in highway safety and to provide necessary reporting to stakeholders and to meet grant funding requirements.

There is significant research potential to explore the return-on-investment for connected technologies. Based on the initial pilot studies presented in this paper, an initial estimate of benefit-to-cost for congestion-based alerts has been calculated to be approximately 30:1 which can be compared to Variable Message Signs which are approximately 11:1. Although the exact values are still under review at the time of submitting this paper, initial calculations show a promising return on investment compared to traditional traffic information systems.

Even high-level benefit-to-cost comparisons of in-cab alerts versus traditional technologies highlight the benefits of integrating a connected technology program. Whereas in-cab alerts are available on ELDs (which are mandated to be present and always-on in commercial motor vehicles across the country), traditional technologies (telephone, websites, message signs, etc.) provide safety-critical information that

may not be received or understood by all impacted vehicles. Furthermore, in the case of infrastructure-dependent solutions such as message signs, there are significant initial hardware costs, and recurring operational and maintenance costs, which are not applicable when deploying advanced connected software solutions.

Even in cases where traditional technologies do not rely on infrastructure, the return on investment is arguably still lower when considering the decreased reach and usage (these solutions are manual and do not have the ability to directly communicate with all impacted vehicles). For example, a 2005 research report conducted by the Washington State Transportation Center and University of Washington, estimated that the 511 telephone service cost approximately $300,000 USD per year. However, the service was only used by 12% of respondents in the report (17). Additionally respondents are required to call in manually to use the 511 service, so real-time alerts and updates may not be received by drivers in a timely manner, if at all, lowering the return on investment.

In addition to saving lives with minimal financial investment, in-cab alerts on a connected network can add value to safety programs by reducing emissions and providing insights into driver behavior. Detailed research into the benefit-to-cost of implementing in-cab alerts is underway and the results can be refined with the expansion and addition of safety pilot programs.

Vision Zero: What Does the Road to Success Look Like?

According to the Road to Zero Coalition, the Road to Zero Vision relies on accelerating advanced technologies.

A commitment to a Safe System Approach to roadway safety will entail analyzing safety problems, identifying solutions with a high return on investment, and implementing these improvements system-wide to prevent incidents and crashes from occurring.

The in-cab alert safety programs explored in this paper, a technology that can currently be deployed quickly and effectively across a connected truck network, is just one example of existing technologies that can save lives on our roads. Automatic emergency braking, adaptive cruise control, lane-keeping are other examples that are showing promising results. Regardless of which specific solutions are selected, adoption and acceleration of any technological developments will rely on strong partnerships between agencies, manufacturers, technology and data providers, emergency systems, public safety and health groups, and roadway users, amongst others, to ensure that these technologies are rolled out efficiently for maximized safety program results (18)—with the goal of reaching the end of our envisioned road sooner, where zero fatalities is the destination.

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