Accident Analysis and Prevention 121 (2018) 177–184

Contents lists available at ScienceDirect

Accident Analysis and Prevention

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

Do the benefits outweigh the costs? Societal benefit-cost analysis of three large truck safety technologies

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ARTICLE INFO

Keywords:
Large truck
Society
Automatic emergency braking
Lane departure warning
Video onboard monitoring
Benefit cost analysis

ABSTRACT

Although research has found advanced safety technologies to be effective at preventing large truck crashes, limited empirical data exists regarding their cost effectiveness to the U.S. society. Without these data, carriers are hesitant to adopt costly technologies and government agencies are hesitant to create regulation mandating their use. The objective of this study was to provide scientifically-based estimates of the societal benefits and costs of large truck automatic emergency braking (AEB), lane departure warning (LDW), and video-based onboard safety monitoring (OSM). For each technology, benefit-cost analyses were performed for installing the technology on all large trucks (including retrofitting existing trucks) and for equipping new large trucks only. Sensitivity analyses examined three cost estimates (low, average, high; values technology-specific), two estimates of system efficacy (low and high; values technology-specific), and three discount rates (0%, 3%, 7%) for each technology. Equipping trucks with LDW and video-based OSM systems were found to be cost effective for all combinations of costs, efficacy, and discount rates examined, for both new and existing trucks. Results for AEB and were mixed. Only a $500 AEB system was cost effective when equipping new trucks and retrofitting existing trucks. However, all cost estimates were cost effective with a 28% efficacy rate when only equipping new large trucks. Overall, these data suggested all three technologies can be cost-effective for new large trucks provided the current costs and efficacy rates can be maintained or improved upon.

1. Introduction

Technological advances over the previous decade have accelerated the rise of large truck advanced safety technologies (ASTs). ASTs often use sensors or alerts to warn a driver of a possible collision. Other ASTs go a step further and have the ability to actively assume lateral and/or longitudinal control of a vehicle in situations where a driver does not react to the threat of an imminent crash. Additionally, a third group of ASTs collect driver data with onboard cameras and/or sensors to be used as a training tool to reduce risky driving behaviors. Although there are a wide variety of ASTs in the large truck market, the efficacy of very few ASTs have been empirically evaluated. Even fewer have been empirically evaluated in real-world operating conditions. Three of the large truck ASTs that have been empirically evaluated in real-world operating conditions include automatic emergency braking (AEB) systems, lane departure warning (LDW) systems, and video-based onboard safety monitoring (OSM) systems.

1.1. Automatic emergency braking (AEB) systems

AEB systems monitor the forward roadway with cameras and/or sensors to detect potential front-to-rear collision threats (and, with less effectiveness, head-on collisions). First, the AEB system will alert the driver if it detects a possible front-to-rear collision given the current rate of speed and lane position. The driver will then have the opportunity to decrease the threat of the collision by changing lanes or slowing down. However, if the driver continues at the same speed and headway (thereby further reducing the time-to-collision) and the AEB system determines a front-to-rear crash will occur without intervention, the truck's brakes will automatically be applied to mitigate or prevent the imminent crash.

Previous research has found that large truck AEB systems may prevent between 16% and 52.3% of front-to-rear crashes where the large truck struck the back of another vehicle (Hickman et al., 2013; Jermakian, 2012; Kuehn et al., 2011; Woodrooffe et al., 2012). Much of this variation in efficacy was due to generational differences in

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https://doi.org/10.1016/j.aap.2018.09.013
Received 8 May 2018; Received in revised form 28 August 2018; Accepted 13 September 2018
0001-4575/

performance capabilities of AEB systems (i.e., ability to brake to stationary objects, 0.3 g versus 0.6 g braking). Furthermore, there were differences between studies in how crash reductions were calculated (e.g., using carrier-owned crash data, national crash statistics, or test track data). In addition to these scientific studies, large truck fleets have reported much higher reductions in rear-end crashes with the adoption of AEB (Berg, 2016; Birkland, 2016; National Transportation Safety Board, 2015; Smith, 2017). However, without information on how crash reductions were calculated, it is difficult to compare these reductions to the empirical research.

1.2. Lane departure warning (LDW) systems

Unlike AEB, LDW systems do not assume control of the truck. Instead, LDW systems use machine vision to monitor the truck's position between lane lines. If the truck begins to deviate over a lane line, the LDW system will provide the driver with a directional warning. For example, if the truck begins to cross the right lane line, the LDW will provide an alert from the right side speaker in the truck cab. Further the LDW system will only provide an alert if the truck's turn signal is not activated. Alerting drivers to unintentional lane deviations will potentially reduce same direction and opposite direction sideswipes initiated by the large truck, large truck road departures not resulting from a purposeful evasive maneuver, and head-on crashes where the large truck deviated into an oncoming lane.

Ten empirical studies have evaluated the potential sideswipe, road departure, and head-on crash reductions associated with the adoption of large truck LDW systems. These studies found large truck LDW systems may prevent between 13% and 53% of all large truck same direction and opposite direction sideswipes, road departures, and head-on collisions (Houser et al., 2009; Hickman et al., 2013; Jermakian, 2012; Johnson, 2008; Kingsley, 2009; Kuehn et al., 2011; Nodine et al., 2011; Orban et al., 2006; Pomerleau et al., 1999; Visvikis et al., 2008). As with AEB, much of this variation was due to how crash reductions were calculated (e.g., using carrier-owned crash data, national crash statistics, or test track data).

1.3. Video-based onboard safety monitoring (OSM) systems

Video-based OSM systems are unlike the other two AST described. Video-based OSM systems use in-vehicle cameras to monitor driver behavior and the environment surround the truck. Typically, video-based OSM system include a forward-facing camera and a driver-facing camera. The data provided by the cameras are combined with vehicle telematics data to identify instances of potentially risky situations. Additionally, some of these technologies incorporate immediate, in-vehicle driver alerts whenever the system detects a potentially unsafety event. The combination of these data allow a fleet manager to proactively coach drivers to reduce driving errors and risky driving behaviors. Thus, the target crash population for video-based OSM systems includes all preventable large truck crashes caused by driver errors or risky driving behaviors.

Only two empirical studies have evaluated the efficacy of video-based OSM systems. These studies found that video-based OSMs may prevent between 38.1% and 52.2% of large truck safety critical events, 20% of fatal large truck crashes, and 35.5% of large truck crashes that result in injury (Hickman and Hanowski, 2010; Soccolich and Hickman, 2014). Despite only two empirical studies, many fleets have decided to adopt video-based OSM systems. Technology vendors have published case studies for some of these fleets showing large truck crash reductions between 55% and 80% (Lytx, 2016a,b,c; SmartDrive, 2013a,b).

1.4. Rationale and purpose

Although research has found these ASTs are effective at preventing large truck crashes, limited empirical data exists regarding their cost effectiveness to individual carriers or to the U.S. society as a whole. Without these data, adoption rates are slow as carriers are hesitant to adopt costly technologies and government agencies are hesitant to create regulation mandating their use.

The purpose of this study was to bridge this gap in the existing research. This study used existing efficacy data to estimate the societal benefits and costs of large truck AEB, LDW, and video-based OSM systems. In other words, this study used the efficacy rates found in previous empirical research and compared these to cost effectiveness (i.e., compare the financial benefits associated with preventing crashes to the implementation costs in the U.S. society).

2. Materials and methods

To accomplish this project's objective, an Expert Advisory Panel selected each AST's cost and efficacy rates. Experts on this panel represented a commercial motor vehicle carrier, a trucking insurance company, the Federal Motor Carrier Safety Administration (FMCSA), the National Highway Traffic Safety Administration (NHTSA), an AST technology vendor, and an industry safety consultant. The purpose of this Expert Advisory Panel was to identify the appropriate efficacy rates and costs for each AST and the specific crash types that they may prevent. In an attempt to improve the quality of the Expert Advisory Panel's recommendation, the project used the Delphi method. First, the authors provided the Expert Advisory Panel a detailed summary of the previous research on the technologies of interest. This summary included a description of the research methodologies, the efficacy results, and the technology costs. Each expert independently reviewed this information, and provided a written recommendation for which technologies should be included in the benefit-cost analysis (BCA) and their recommendations for the efficacy rates and costs with the greatest potential to be realized. The authors compiled these recommendations and presented these results at an in person Expert Advisory Panel meeting held in Washington, D.C. The experts were asked to discuss and debate the appropriateness of these recommendations. After this discussion, the experts were asked to reevaluate their recommended efficacy rates and costs. This process resulted in a convergence of recommendations where the Expert Advisory Panel agreed on efficacy rates and costs for each of the selected ASTs.

During this process the Expert Advisory Panel used four criteria to weigh previous research. First, light vehicle AST efficacy rates were not considered. AST efficacy is greatly impacted by vehicle. As this study only considered large truck ASTs, only research using large truck ASTs was considered. Second, research using data generated during normal revenue-producing operations was weighted over research only using simulators or statistical modeling techniques. ASTs may perform differently in real-world conditions compared to best-case scenarios often used in statistical modeling studies. If real-world data were unavailable, data generated from actual vehicle testing was weighted over data from simulators or statistical modeling techniques. Third, efficacy rates from data in the U.S. were weighted over data generated in other parts of the world. This was because the efficacy rates were to be applied to U.S. crash data. Thus, it is important, if possible, to apply the efficacy rates to crashes in which the data were original generated. Finally, research with efficacy rates for relevant crash types was prioritized over efficacy rates for overall crash. This allowed the authors to calculate more precise reductions in crashes. Furthermore, the experts chose conservative efficacy rates to avoid overstating each AST's potential crash reduction and cost effectiveness.

Following a review of the existing literature, the expert panel agreed on the following for AEB, LDW, and video-based OSM systems: (1) the crash types that each may prevent, (2) upper- and lower-bound efficacy rates, and (3) low, average, and high purchase costs. Table 1 shows the recommendations from the expert panel along with the references from the efficacy rates and costs.

The efficacy rates for AEB were selected from Woodrooffe et al.