Journal of Safety Research 52 (2015) 59–63

Contents lists available at ScienceDirect

Journal of Safety Research

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

Efficacy of roll stability control and lane departure warning systems using carrier-collected data

Jeffrey S. Hickman [a,*], Feng Guo [a,b], Matthew C. Camden [a], Richard J. Hanowski [a], Alejandra Medina [a], J. Erin Mabry [a]

[a] Virginia Tech Transportation Institute, USA
[b] Department of Statistics, Virginia Polytechnic Institute and State University, USA

ARTICLE INFO

Article history:
Received 19 August 2014
Received in revised form 6 November 2014
Accepted 9 December 2014
Available online 7 January 2015

Keywords:
Roll stability control
Lane departure warning
Truck
Crash
Carrier data

ABSTRACT

Introduction: Large truck crashes have significantly declined over the last 10 years, likely due, in part, to the increased use of onboard safety systems (OSS). Unfortunately, historically there is a paucity of data on the real-world efficacy of these devices in large trucks. The purpose of this study was to evaluate the two OSSs, lane departure warning (LDW) and roll stability control (RSC), using data collected from motor carriers. *Method:* A retrospective cohort approach was used to assess the safety benefits of these OSSs installed on Class 7 and 8 trucks as they operated during normal revenue-producing deliveries. Data were collected from 14 carriers representing small, medium, and large carriers hauling a variety of commodities. The data consisted of a total of 88,112 crash records and 151,624 truck-years that traveled 13 billion miles over the observation period. *Results:* The non-LDW cohort had an LDW-related crash rate that was 1.917 times higher than the LDW cohort ($p = 0.001$), and the non-RSC cohort had an RSC-related crash rate that was 1.555 times higher than the RSC cohort ($p < 0.001$). *Conclusions:* The results across analyses indicated a strong, positive safety benefit for LDW and RSC under real-world conditions. *Practical applications:* The results support the use of LDW and RSC in reducing the crash types associated with each OSS.

1. Introduction

In 2000 there were 4,995 large truck crashes that resulted in a fatality and 351,000 property-damage-only. Eleven years later there were 3,608 large truck crashes that resulted in a fatality and 221,000 property-damage-only crashes (National Highway Traffic Safety Administration, 2013). Although these numbers are encouraging, there are still far too many fatalities and injuries due to large truck crashes. One possible way to reduce the number of large trucks crashes and their associated fatalities and injuries is through the expanded use of onboard safety systems (OSS), such as lane departure warning (LDW) systems and roll stability control (RSC) systems. LDW systems are in-vehicle electronic systems that monitor the position of a vehicle within a roadway lane and warn a driver if the vehicle deviates or is about to deviate outside the lane. RSC systems monitor vehicle dynamics and estimate the stability of a vehicle based on its mass and velocity (i.e., actively reduce the vehicle's throttle and apply its brakes to decelerate the vehicle if a high rollover risk is detected).

Several published studies have shown the efficacy of LDW and RSC to reduce passenger car crashes (Farmer, 2006; Green & Woodrooffe, 2006; Johnson, 2008); however, there is a paucity of data of the potential efficacy of LDW and RSC in large trucks. The large trucks studies that have evaluated the potential benefits of these systems used simulators (Houser, Pape, & McMillian, 2006), statistical modeling (Abele et al., 2005; Battelle, 2007; Pomerleau et al., 2000), or crash rates obtained from large national or state crash databases (Houser, Murray, Shackelford, Kreeb, & Dunn, 2009; Murray, Shackelford, & Houser, 2009a; Visvikis, Smith, Pitcher, & Smith, 2008) to illustrate the effectiveness of these systems in reducing large truck crashes.

Prior research on the efficacy of LDW at the individual truck level as these trucks operate in the real world under normal driving conditions and daily driving pressures is limited. Thus, information about the real-world effectiveness of these OSSs will be valuable in advancing their further use in the trucking industry. The Integrated Vehicle-based Safety Systems program (Sayer et al., 2011) evaluated an integrated crash warning system with 10 instrumented Class 8 trucks over a 10-month period. The integrated system included LDW as well as forward collision warning. Although the study found no effect on lane departure frequency (but a trend toward a decrease in lane departures in 13 of the 18 drivers), drivers reported that the integrated system made them more aware of the traffic environment around their vehicles and their position in the lane. The study did not evaluate possible reductions in crashes or safety-related events, such as near crashes.

The objective of the current study was to address the limitations noted above to evaluate the efficacy of LDW and RSC in reducing crashes in trucks associated with each OSS using real-world, carrier-collected

* Corresponding author at: Virginia Tech Transportation Institute, 3500 Transportation Research Plaza, Blacksburg, VA 24061, USA. Tel.: +1 540 231 1442.
E-mail address: jhickman@vtti.vt.edu (J.S. Hickman).

http://dx.doi.org/10.1016/j.jsr.2014.12.004
0022-4375/

data. To accomplish this, the current study: (a) used data collected directly from participating carriers; thus, the resultant data set used in the analyses contains a broad spectrum of crashes (many of these crashes were not reported to State or Federal agencies and represent the crash spectrum experienced by truck carriers); (b) collected detailed information on the trucks and the safety management techniques at the participating carriers; thereby, allowing the control of variables that may have influenced the crash rate; (c) collected mileage information from each truck to control for differences in exposure; and (d) reviewed each crash file to determine if the specific OSS would have mitigated or prevented the crash. The current study assessed the safety benefits of LDW and RSC installed on Class 7 and 8 trucks [gross vehicle weight greater than 26,000 lbs (11,794 kg)] as they operated during normal revenue-producing deliveries. The data collected from the participating carriers were used to answer two specific research hypotheses:

- *Research hypothesis 1*: RSC will significantly reduce the crash rate of specific crash types associated with RSC (i.e., RSC-related crashes).
- *Research hypothesis 2*: LDW will significantly reduce the crash rate of specific crash types associated with LDW (i.e., LDW-related crashes).

2. Methods

Participating fleets were recruited based on several carrier selection recommendations, including at least two calendar years of data, required data elements to conduct the analyses, and LDW and/or RSC installed on some of their trucks (carriers without LDW and RSC were also recruited). The research team cultivated relationships with many different motor carriers; these carriers were contacted via email and/or phone to determine if they met the necessary selection criteria for participating in the current study and, if they did, to request participation. To increase participation, an advertisement was also placed in *Transport Topics* requesting participation from interested carriers.

Collection of carrier data began after the non-disclosure agreement (NDA) was signed and returned by the participating carrier. After the NDA was returned, the research team worked with each carrier's representative to collect the necessary data. Carriers sent the research team an Excel spreadsheet (via email, on a CD via US Mail, or via ftp transfer) with carrier-collected crash and vehicle data (e.g., yearly mileage and OSS status). This usually involved an iterative process as certain data variables were missing and/or further explanation was needed regarding the meaning of codes included in the data set. The carriers also identified the specific type of RSC and LDW systems installed on each truck. These systems were compared to a literature search by Hickman et al. (2013) to determine if the technologies were appropriate for inclusion in the study. The literature review identified effective OSS technologies through books, trade journals, product brochures, manufacturers' press releases, manufacturers' Web sites, and trade magazine Web sites. None of the RSC or LDW technologies reported by the participating carriers were deemed out of date or inappropriate. No information was provided by the carrier regarding how the OSS was installed on the truck.

The research team collected existing motor carrier data from 14 participating carriers to evaluate the effectiveness of LDW and RSC. LDW systems were expected to reduce single-vehicle roadway departures, same direction lane departures, and opposite direction lane departures. RSC systems were expected to reduce rollover crashes involving combination trucks. At a minimum, participating carriers provided at least 2 years of existing crash data from calendar years 2007, 2008, and 2009 (one participating carrier provided data from 2010).

Some carriers provided traditional crash files whereas other carriers provided crash files that also included claims data (the claims data were present as the carrier was self-insured). An example of a claim might be a driver driving over a bush in a customer's parking lot, scrapping a mirror against an object, or the security arm at a gate coming down on the truck's hood and damaging the truck. As described below, these claims were filtered out of the analyses regarding the efficacy of the OSSs; however, they were included in the overall crash analysis. Thus, the overall crash rate was inflated (as it contains crashes and claims) and should be viewed with caution.

2.1. Data merging and reduction

As the data sets provided by each carrier were not identical, all data sets were merged and formatted into one large data set with common headings. Table 1 displays the operational definitions for the uniform crash types associated with each OSS and whether these crash types could have been prevented or mitigated by one of the OSSs. Once this was complete, data analysts recoded the crash type for each crash file (using the existing crash type and crash narrative) using a uniform list of crash types created by the research team. The crash types coded by data analysts referred to the first impact (e.g., a vehicle that encroached the truck's lane, thereby causing the truck driver to make an avoidance maneuver that resulted in the truck rear-ending another vehicle would be coded as a rear-end collision).

Using the crash narrative, crash type, and other data elements (e.g., contributing factor), data analysts also indicated if the crash could have been prevented or mitigated by each OSS. Even if the crash type corresponded to the specified OSS, there were situations in which the OSS would not be effective. For example, LDW would not provide benefit in a situation where a vehicle encroached the truck's lane; thereby causing the truck driver to make an avoidance maneuver that resulted in the truck running off the road. Table 2 includes a list of situations where LDW and RSC were assessed as being ineffective. Data analysts did not code the crash as an LDW-related or RSC-related crash if any of these situations or circumstances in Table 2 were present. Thus, a LDW-related crash and RSC-related crash included the crash types noted in Table 1 unless one of the situations in Table 2 was identified by data analysts during their review of the crash file. The total number of LDW-related crashes was 6,705. Of these, 4,301 were eliminated through the data reduction process (for a total of 2,404 valid LDW-related crashes). The total number of RSC-related crashes was 848. Of these, 183 were eliminated through the data reduction process (for a total of 665 valid RSC-related crashes).

Inter-rater reliability (i.e., agreement on the coding made by the data analyst and the third author) was performed on approximately 30% of the data analysts' coding with respect to identifying the crash type (e.g., the crash was a sideswipe, same direction) and if a crash was designated as LDW-related or RSC-related. When reliability was performed, the data analysts' coding was compared to the coding on the identical crash file made by the first author (a senior member of the research team). Inter-rater reliability on the crash type and validity of the LDW-related and RSC-related designation was 96.4% and 99.7%, respectively. When there was a discrepancy, the coding made by the third author was used.

Table 1
Operational definitions for the uniform crash types associated with each OSS.

Crash type	Operational definition	OSS
Runoff road	The truck runs off the road and the road and/or surface causes damage to the truck.	LDW
Headon	The truck had a head-on collision with another vehicle on the roadway.	LDW
Sideswipe	The truck struck another vehicle/object traveling in the same direction on its side.	LDW
Opposite sideswipe	The truck struck another vehicle/object traveling in the opposite direction on its side.	LDW
Rollover	The first impact is the truck rolling over.	RSC