Journal of Safety Research xxx (2018) xxx–xxx

Contents lists available at ScienceDirect

Journal of Safety Research

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

Effects of lane departure warning on police-reported crash rates

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ARTICLE INFO

Article history:
Received 16 August 2017
Received in revised form 21 February 2018
Accepted 8 May 2018
Available online xxxx

Keywords:
Crash avoidance technology
Collision warning
Driver assistance
Single-vehicle run-off-road
Sideswipe
Head-on collision

ABSTRACT

Objective: To evaluate the effects of lane departure warning (LDW) on single-vehicle, sideswipe, and head-on crashes. *Method:* Police-reported data for the relevant crash types were obtained from 25 U.S. states for the years 2009–2015. Observed counts of crashes with fatalities, injuries, and of all severities for vehicles with LDW were compared with expected counts based on crash involvement rates for the same passenger vehicles without LDW, with exposure by vehicle series, model year, and lighting system standardized between groups. For relevant crashes of all severities and those with injuries, Poisson regression was used to estimate the benefits of LDW while also controlling for demographic variables; fatal crashes were too infrequent to be modeled. *Results:* Without accounting for driver demographics, vehicles with LDW had significantly lower involvement rates in crashes of all severities (18%), in those with injuries (24%), and in those with fatalities (86%). Adding controls for driver demographics in the Poisson regression reduced the estimated benefit of LDW only modestly in crashes of all severities (11%, $p < 0.05$) and in crashes with injuries (21%, $p < 0.07$). *Conclusions:* Lane departure warning is preventing the crash types it is designed to address, even after controlling for driver demographics. Results suggest that thousands of lives each year could be saved if every passenger vehicle in the United States were equipped with a lane departure warning system that performed like the study systems. *Practical applications:* Purchase of LDW should be encouraged, and, because drivers do not always keep the systems turned on, future efforts should focus on designing systems to encourage greater use and educating consumers about the benefits of using the systems.

1. Introduction

Crashes resulting from lane departures can be among the deadliest collisions. In 2015, nearly 13,000 people died in single-vehicle run-off-road, head-on, and sideswipe crashes where a passenger vehicle left the lane unintentionally (Insurance Institute for Highway Safety, 2017). Technology designed to help drivers avoid unintentional lane departures can prevent these crashes. Electronic stability control, which can prevent lane departures due to loss of control, has been shown to reduce fatal single-passenger- vehicle crash risk by 49% (Farmer, 2010).

Other technologies aim to keep drivers from drifting out of lanes, either by providing warnings or steering corrections when they cross a lane line without signaling or by actively centering them within their lanes. Lane departure warning first became available in the United States on the Infiniti FX35 in model year 2005 and is becoming increasingly available on new passenger vehicles. In model year 2017, lane departure warning was available on 63% of new U.S. passenger vehicle series as standard (6%) or optional (57%) equipment (Highway Loss Data Institute [HLDI], 2016a).

Jermakian (2011) estimated that if every passenger vehicle in the United States were equipped with lane-keeping technology that prevented all relevant crashes, up to 3% of crashes of all severities, 5% of crashes with serious or moderate injuries, and 23% of fatal crashes involving passenger vehicles could be prevented. If all large trucks were equipped with these systems, they could potentially prevent 3% each of crashes of all severities and with serious or moderate injuries, and 6% of fatal crashes involving these vehicles (Jermakian, 2012). However, real-world evidence on the effectiveness of lane departure warning systems has been mixed.

Hickman et al. (2015) studied the effect of lane departure warning on large trucks using carrier-collected data from 14 U.S. fleets. Trucks equipped with lane departure warning had crash rates per mile traveled in single-vehicle run-off-road, head-on, and sideswipe crashes deemed relevant to the technology that were 48% lower than the rate for trucks without lane departure warning.

Sternlund, Strandroth, Rizzi, Lie, and Tingvall (2017) used induced exposure to investigate the effectiveness of lane departure warning and prevention (i.e., systems that warn or provide steering correction) on Volvo passenger cars in Sweden. The ratio of single-vehicle and head-on crash involvements with injuries, which were deemed relevant to lane departure warning and prevention, to rear-struck crash involvements with injuries, which were assumed to be unaffected by the technologies, was compared between Volvo vehicles with lane departure warning or prevention and the same vehicle models without the optional systems. Crashes relevant to lane departure warning and

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https://doi.org/10.1016/j.jsr.2018.05.006
0022-4375/

Please cite this article as: Cicchino, J.B., Effects of lane departure warning on police-reported crash rates, *Journal of Safety Research* (2018), https://doi.org/10.1016/j.jsr.2018.05.006

prevention were further limited to those occurring on roads with speed limits of 70–120 kph and that were not covered with ice or snow to align with system limitations. Volvo's lane departure warning and prevention systems reduced relevant crashes by 53%.

Positive benefits for lane departure warning have not yet been seen among passenger vehicles in the United States. HLDI (2012, 2016b, 2016c, 2016d, 2017a, 2017b) compared insurance claim rates for passenger vehicles insured in the United States with lane departure warning from a number of manufacturers to the same make, series, and model year vehicles without it, controlling for other collision avoidance systems on the vehicles and characteristics of the rated driver on the insurance policy. Lane departure warning always came bundled with a front crash prevention system (forward collision warning with or without autonomous emergency braking) on the vehicles from most manufacturers that HLDI examined, which made it difficult to tease out system-specific effects. On Mercedes-Benz and Mazda vehicles, where lane departure warning did not always come bundled with another system and effects could be isolated, no benefits for the system were found.

It is possible that the crash types that can potentially be prevented by lane departure warning, which make up a relatively small proportion of the total crash population (Jermakian, 2011), appear too infrequently in HLDI's database to be detected by an overall claim rate analysis. Effects of the system on crash types affected by the system could not be examined in HLDI's work because their data do not contain detailed information on crash circumstances. The goal of the current study was to examine the effect of lane departure warning on single-vehicle, head-on, and sideswipe crashes relevant to the system in the United States using police-reported crash data, where crash types could be identified. Crash involvement rates per insured vehicle year in crash types relevant to lane departure warning of all severities, with injuries, and with fatalities were compared between vehicles with lane departure warning and the same make, series, and model year vehicles without the optional system.

2. Method

2.1. Vehicles

Vehicle series and model years included in the analyses are listed in Table 1. Study vehicles were limited to those where lane departure warning was offered as an optional feature and the presence or absence of the system on individual vehicles at the VIN (vehicle identification number) level was known. The study focused on vehicles with optional lane departure warning systems because these systems were rarely offered as standard equipment at the time of the study.

VINs of General Motors (Buick, Cadillac, Chevrolet, and GMC), Mazda, Mercedes-Benz, and Volvo vehicles equipped with various collision avoidance technologies, including lane departure warning, were obtained from manufacturers. Collision avoidance systems on Honda and Subaru vehicles that were examined in this study were decodable from the VIN.

Lane departure warning systems from Honda, Subaru, and Volvo warned drivers with audible beeps, while Mercedes-Benz vehicles warned with steering wheel vibrations. Mazda offered a choice of beeps or a sound mimicking driving over a rumble strip. Some General Motors vehicles offered only a beeping warning and others offered a choice of a beeps or directional seat vibrations. Systems were operational beginning at speeds ranging from 30 to 44 mph.

Collision avoidance systems other than lane departure warning were offered on many study vehicles. The presence of headlight and other nighttime visibility systems that could potentially impact lane departure crashes that occur in the dark were controlled for in analyses. These systems were:

- *General Motors:* high-intensity discharge headlights; curve-adaptive high-intensity discharge headlights; high-beam assist; cornering lamps
- *Honda:* LED headlights
- *Mazda:* curve-adaptive high-intensity discharge headlights; high-beam assist (packaged with forward collision warning)
- *Mercedes-Benz:* night vision system; high-intensity discharge headlights, curve-adaptive high-intensity discharge headlights, high-beam assist, and cornering lamps (the four headlight systems were packaged together on >99% of study vehicles)
- *Volvo:* curve-adaptive high-intensity discharge headlights

When an advanced headlight type was optional, the base headlights were halogen for all manufacturers. Subaru offered high-intensity discharge headlights as an option, but their presence or absence on individual vehicles was unknown; thus, headlights were not accounted for in analyses involving Subaru vehicles. LED headlights were standard on some General Motors series and could not be controlled for separately because they were never optional equipment.

Other optional collision avoidance systems were not expected to affect crashes relevant to lane departure warning and were not accounted for in analyses. These features were sometimes, but not always, packaged with lane departure warning, and included side-view assist, rear cross-traffic alert, rearview cameras, front and rear parking sensors, rear

Table 1
Study vehicle series and model years.

Make	Series	Model years
Buick	LaCrosse 4D 2WD	2014–2015
Buick	LaCrosse 4D 4WD	2014–2015
Buick	Regal 4D 2WD	2014–2015
Buick	Regal 4D 4WD	2014–2015
Cadillac	ATS 4D 2WD	2013–2014
Cadillac	ATS 4D 4WD	2013–2014
Cadillac	CTS 4D 2WD	2014
Cadillac	CTS 4D 4WD	2014
Cadillac	Escalade 4D 2WD	2015
Cadillac	Escalade 4D 4WD	2015
Cadillac	Escalade ESV 4D 2WD	2015
Cadillac	Escalade ESV 4D 4WD	2015
Cadillac	SRX 4D 2WD	2013–2015
Cadillac	SRX 4D 4WD	2013–2015
Cadillac	XTS 4D 2WD	2013–2014
Cadillac	XTS 4D 4WD	2013–2014
Chevrolet	Impala 4D	2014–2015
Chevrolet	Suburban 4D 2WD	2015
Chevrolet	Suburban 4D 4WD	2015
Chevrolet	Tahoe 4D 2WD	2015
Chevrolet	Tahoe 4D 4WD	2015
GMC	Yukon 4D 2WD	2015
GMC	Yukon 4D 4WD	2015
GMC	Yukon XL 4D 2WD	2015
GMC	Yukon XL 4D 4WD	2015
Honda	Accord 2D	2013–2015
Honda	Accord 4D	2013–2015
Honda	Accord Crosstour 4D 2WD	2013–2015
Mazda	3 4D	2014–2015
Mazda	3 5D	2014–2015
Mazda	6 4D 2WD	2014–2015
Mercedes-Benz	E Class 4D 2WD	2010
Mercedes-Benz	E Class 4D 4WD	2010
Mercedes-Benz	S Class Hybrid 4D 2WD	2010
Mercedes-Benz	S Class LWB 4D 2WD	2010
Mercedes-Benz	S Class LWB 4D 4WD	2010
Subaru	Forester 4D 4WD	2014–2016
Subaru	Impreza 4D 4WD	2015–2016
Subaru	Legacy 4D 4WD	2013–2016
Subaru	Outback SW 4WD	2013–2016
Volvo	S80 4D 2WD	2008–2010
Volvo	S80 4D 4WD	2008–2010
Volvo	V70 SW 2WD	2008–2010
Volvo	XC60 4D 2WD	2010
Volvo	XC60 4D 4WD	2010
Volvo	XC70 SW 4WD	2008–2010

2D = two-door, 4D = four-door, 5D = five door, 2WD = two-wheel drive, 4WD = four-wheel drive, SW = station wagon, LWB = long wheelbase.

Please cite this article as: Cicchino, J.B., Effects of lane departure warning on police-reported crash rates, *Journal of Safety Research* (2018), https://doi.org/10.1016/j.jsr.2018.05.006