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Cost and benefit estimates of partially-automated vehicle collision avoidance technologies

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ABSTRACT

Many light-duty vehicle crashes occur due to human error and distracted driving. Partially-automated crash avoidance features offer the potential to reduce the frequency and severity of vehicle crashes that occur due to distracted driving and/or human error by assisting in maintaining control of the vehicle or issuing alerts if a potentially dangerous situation is detected. This paper evaluates the benefits and costs of fleet-wide deployment of blind spot monitoring, lane departure warning, and forward collision warning crash avoidance systems within the US light-duty vehicle fleet. The three crash avoidance technologies could collectively prevent or reduce the severity of as many as 1.3 million U.S. crashes a year including 133,000 injury crashes and 10,100 fatal crashes. For this paper we made two estimates of potential benefits in the United States: (1) the upper bound fleet-wide technology diffusion benefits by assuming all relevant crashes are avoided and (2) the lower bound fleet-wide benefits of the three technologies based on observed insurance data. The latter represents a lower bound as technology is improved over time and cost reduced with scale economies and technology improvement. All three technologies could collectively provide a lower bound annual benefit of about $18 billion if equipped on all light-duty vehicles. With 2015 pricing of safety options, the total annual costs to equip all light-duty vehicles with the three technologies would be about $13 billion, resulting in an annual net benefit of about $4 billion or a $20 per vehicle net benefit. By assuming all relevant crashes are avoided, the total upper bound annual net benefit from all three technologies combined is about $202 billion or an $861 per vehicle net benefit, at current technology costs. The technologies we are exploring in this paper represent an early form of vehicle automation and a positive net benefit suggests the fleet-wide adoption of these technologies would be beneficial from an economic and social perspective.

1. Introduction

Many light-duty vehicle crashes occur due to human error and distracted driving. The National Highway Traffic Safety Administration (NHTSA) reports that ten percent of all fatal crashes and seventeen percent of injury crashes in 2011 were a result of distracted driving, while close to ninety percent of all crashes occur in part due to human error (NHTSA, 2013a; Olarte, 2011). Recent naturalistic driving data has confirmed the large prevalence of distracted driving and other driver-related factors in crashes (Dingus et al., 2016). Crash avoidance features offer the potential to substantially reduce the frequency and severity of vehicle crashes and deaths that occur due to distracted driving and/or human error by assisting in maintaining control of the vehicle or issuing alerts if a potentially dangerous situation is detected.

As the automobile industry transitions to partial vehicle automation, newer crash avoidance technologies are beginning to appear more frequently in non-luxury vehicles such as the Honda Accord and Mazda CX-9. The availability of Forward Collision Warning (FCW), Lane Departure Warning (LDW), and Blind Spot Monitoring (BSM) technologies could reach 95% of the registered vehicle fleet anywhere between the years 2032 and 2048 (HLDI, 2014a). The market penetration rate of these technologies depends on government mandates that could speed up implementation by up to 15 years (HLDI, 2014a). Automated vehicle technologies could have significant economic net benefits due to crash reduction (including direct cost savings and associated roadway congestion), enabling greater mobility for the disabled and

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elderly, and improved fuel economy due to more efficient driving (Anderson et al., 2014).

This paper estimates the costs and benefits of fleet-wide deployment of BSM, LDW, and FCW crash avoidance systems within the U.S. light-duty vehicle fleet. Two estimates are made to provide insight on current trends and technology potential. First, an upper bound of relevant U.S. crashes that potentially could be avoided or made less severe by the three technologies is estimated, assuming 100% technology effectiveness. Next, a lower bound in U.S. crash reduction is estimated using current changes in observed insurance collision claim frequency and severity (average loss payment per claim) in motor vehicles with these technologies. After these estimates are made, an annualized cost to equip each vehicle with the technologies enables a cost benefit analysis for the lower bound and upper bound estimates of net benefits in the U.S. The technologies we are exploring in this paper represent an early form of vehicle automation as defined by NHTSA (NHTSA, 2013b) and the estimates in this paper can help inform near-term decisions during the transition to automation.

2. Existing literature

Several researchers have analyzed the effectiveness of crash avoidance technologies in reducing crashes and severity. For example, Jermakian (2011) estimates that side-view assist and FCW systems could potentially prevent or reduce the severity of as many as 395,000 and 1.2 million crashes involving passenger vehicles annually, respectively, using crash records from the 2004–2008 National Automotive Sampling System (NASS) General Estimate System (GES) and Fatality Analysis Reporting System (FARS) databases (Jermakian, 2011). Kuehn et al. (2009) used insurance collision claims data along with human factors research and determined that equipping all cars with a forward collision warning and lateral guidance system that was 100% effective, could prevent up to 25% of all crashes (Kuehn et al., 2009). Sugimoto and Sauer (2005) estimated that a FCW system with autonomous braking could reduce the probability of a fatality in a rear end collision by as much 44% (Sugimoto and Sauer, 2005). A 2012 study concluded that Blind Spot Monitoring (BSM) systems could potentially prevent or reduce the severity of 22,000 combination tractor-trailer crashes annually (Jermakian, 2012). Kusano et al. (2014) developed a crash and injury simulation model in which each crash was simulated twice- once as it occurred and once as if the driver had a LDW system-and determined that a LDW system could potentially prevent up to 29.4 percent of all road departure crashes (Kusano et al., 2014). Blower (2013) used simulations and operational field tests to develop a range of estimates on the effectiveness of ESC, LDW, and FCW systems in reducing target crash types (Blower, 2013). The American Automobile Association (AAA) along with the MIT AgeLab conducted a study in which they assessed and provided ratings for both the potential and real world benefits of LDW, FCW, ESC, and other crash avoidance technologies based on data gathered from published literature (Mehler et al., 2014). Blanco et al. (2016) estimated and compared crash risks for self-driving and national crash rates using data from Google's Self-Driving Car program and the Second Strategic Highway Research Program (SHRP 2) Naturalistic Driving Study. This study suggests that less-severe crashes may happen a much lower crash rate for self-driving cars (5.6 per million miles driven) when compared to the national crash rate (14.4 per million miles driven) (Blanco et al., 2016). The Insurance Institute for Highway Safety (IIHS) estimates that forward collision systems with automatic braking could reduce rear-end crashes by about 40% while standalone FCW could reduce these crashes by about 23% (IIHS, 2016).

Researchers have also attempted to estimate the economic benefit of crash avoidance technology systems. For a consistent comparison, we used the consumer price index (CPI) to convert all benefits in previous literature to $2012 (Bureau of Labor Statistics, 2015). One prediction comes from Murray et al. (2009) who found that a FCW system in large trucks could provide a benefit ranging from $1.42 to $7.73 for every dollar spent on the system (Murray et al., 2009). This estimate is based on different vehicle miles traveled (VMTs), system efficacies, and technology purchase prices. Batelle (2007) reports that equipping all large trucks with a FCW system could have a negative net benefit approximately anywhere between −$66 and −27$ billion, depending on the cost of system and driver reaction time (Batelle, 2007). In that study, crash reduction frequencies for a FCW system were derived from statistical modeling. Another study found that at a 90 percent market penetration rate FCW along with adaptive cruise control could provide considerable safety benefits- $52 billion in economic costs (lost productivity, travel delay, etc.) and 497,100 functional person-years (Li and Kockelman, 2016). This paper makes a contribution to the literature by estimating the economic net benefits of three crash avoidance technologies in light-duty vehicles based on changes in observed insurance collision claim frequency and severity for vehicles with BSM, LDW, and FCW crash avoidance systems. We extrapolate the observed insurance data to estimate a lower bound of fleet-wide deployment benefits. It represents a lower bound because technology cost and performance are likely to improve, and additional benefits are likely as deployment increases. To estimate an upper bound, we assume the three crash avoidance technologies examined are 100% effective in preventing relevant crashes.

3. Data

To compute the upper bound annual net benefit of equipping all light-duty vehicles with BSM, LDW, and FCW systems, we first need to identify which types of crashes could potentially be prevented or made less severe by each technology. The primary sources of data used are the 2012 GES which provides information on crashes of all severities, the 2012 FARS which provides information on fatal crashes, and insurance data from various reports written by the Highway Loss Data Institute (HLDI). Table 1 (shown below) provides an overview of the primary data sources for this analysis and their use.

3.1. *Overview of crash avoidance systems*

As mentioned earlier, the crash avoidance systems we focus on for this paper are FCW, LDW, and BSM. FCW systems are intended to detect objects ahead that are stationary or moving at a slower speed and issue a warning to the driver if his or her closing speed represents risk of an impending collision. Many automakers pair FCW with crash imminent braking systems, and both BSM and LDW could be paired with active lane keeping assist technology. LDW systems monitor the lane markings in the roadway and alert the driver if they are drifting out of their own lane. BSM systems monitor the blind spots to the rear and sides of the car and issue a warning if a car enters the driver's blind spot. While these sensors serve the same purpose from vehicle to vehicle, their location on the vehicle could differ by manufacturer. For example, Honda's FCW system is located behind the windshield while Mercedes' and Acura's are located in the front bumper. Similarly, Mazda's BSM system is located in the rear bumpers, while Buick's system is located behind each rear quarter panel. Fig. 1 illustrates how the three crash avoidance systems interact with the roadway.