Safety and Cost Assessment of Connected and Automated Vehicles

FINAL RESEARCH REPORT

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DISCLAIMER

Problem Statement

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

This paper estimates the costs and benefits of large-scale deployment of BSM, LDW, and FCW crash avoidance systems within the light-duty vehicle fleet. Two estimates are made to provide insight on current trends and technology potential. First, an

upper bound of relevant 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 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.

Methodology

The first step in this task is to identify the maximum number of crashes which can be prevented or made less severe by the three technologies. These crashes were identified by using the 2012 FARS and GES databases. For this analysis we only considered one and two-vehicle crashes, which make up about 94% of all vehicle crashes evaluating three or more vehicle crashes adds complexity to the analysis for a small percentage of accidents, and as a result these were not considered. In order to sort crashes into identifiable categories, target crash populations were established, making it easier to estimate the relevant number of crashes for each technology. For this analysis the three target populations are: lane-change crashes, lane-departure crashes, and rear-end collisions, which are most closely related to BSM, LDW, and FCW, respectively. These crash technologies are functional at certain speeds depending on the automaker. Functional speeds of technology were also taken into account when filtering data.

First, it is assumed that a change (positive or negative) in collision claim frequency is the equivalent change in crash frequency for single and multiple-vehicle

accidents. Second, it is assumed that a change in collision claim severity is the equivalent change in crash cost for related accidents which are not prevented. Finally, it is assumed that the three crash avoidance technologies examined are 100% effective.

Next, we estimate the lower bound annual fleet-wide benefits of prevented and less severe crashes from the three technologies. Prevented crash benefits were estimated by multiplying the change in collision claim frequency and the upper bound associated crashes along with the average cost of a crash. Benefits from less severe crashes were found by multiplying the number of crashes which would not be avoided and the money saved from lower collision claim amounts. The only cost for this analysis is assumed to be fleet-wide technology purchasing costs.

Finally, we estimate an upper bound benefit; we assume the three crash avoidance technologies examined are 100% effective in preventing relevant crashes. The net benefit is then calculated by taking the difference between the upper bound benefit and total technology purchasing costs.

Data Sources

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.

Table 1 Overview of Primary Data Sources and Their Use

Data Source	Use	Publisher
2012 National Automotive Sampling System (NASS) General Estimate System (GES)	Estimate Relevant Non-Fatal Crashes	NHTSA
2012 Fatality Analysis Reporting System (FARS)	Estimate Relevant Fatal Crashes	NHTSA
The 2010 Economic and Societal Impact of Motor Vehicle Crashes Report	Estimate Crash Cost	NHTSA
Basav et al.'s Analysis of Lane Change Crashes Report	Identify Lane Change Crashes in FARS and GES	NHTSA
Gordon et al.'s Safety Impact Methodology for Lane Departure Warning Report	Identify Lane Departure Crashes in FARS and GES	NHTSA
A Collection of Collision Avoidance Reports	Estimate Changes in Collision Claim Frequency and Severity	Highway Loss Data Institute (HLDI)

Results and Recommendations

Lower Bound Net-Benefit

In order to analyze the current economic feasibility, the annual net benefit (NB) was estimated. It is shown in Table 1 that the current annual net benefit of widespread deployment of crash avoidance technologies in light-duty vehicles is positive, which

means that the benefits currently exceed the costs. In monetary value, the annual expected net benefit of equipping all light-duty vehicles with a BSM, LDW, and FCW system is about $4 billion. The positive net benefit can be largely attributed to the low cost of the technologies.

Table 1 Lower Bound Annual Net Benefit of Widespread Deployment of Crash Avoidance Technologies in Light-Duty Vehicle Fleet

Description	Current Net Benefit (Billion $2012)
	Value
Total Annual Benefits (TB)	$18
Total Annual Costs (TC)	$13
Annual Net Benefit (NB)	$4

Note: Figures may not sum exactly due to rounding.

Maximum Net-Benefit

Similarly to the lower bound annual net benefit, the upper bound annual net benefit is positive since the upper bound annual benefits far exceed current annualized technology costs. As shown in Table 2, the upper bound annual net benefit from all three technologies collectively at current technology prices, is about $216 billion.

Table 2 Upper Bound Annual Net Benefit of Widespread Deployment of Crash Avoidance Technologies in Light-Duty Vehicle Fleet

Description	Upper Bound Net Benefit
	Value (Billion $2012)
Total Annual Benefits (TB)	$229
Total Annual Costs (TC)	$13
Annual Net Benefit (NB)	$216

Note: Upper bound annual net benefit represents an upper bound that is dependent on the current price of crash avoidance technologies

Discussion

Approximately 23 percent of all crashes are relevant to one of the three crash avoidance technologies: blind spot monitoring, lane departure warning, and forward collision warning. All three technologies could collectively prevent or reduce the severity of as many as 1.3 million crashes a year including 133,000 injury crashes and 10,000 fatal crashes. FCW systems would address the greatest number of crashes overall and injury crashes, while a LDW could affect the largest number of fatal crashes.

In order to conduct a net-benefit analysis to evaluate the economic feasibility of crash avoidance systems in light-duty vehicles, it was assumed crash frequency and crash cost mirrored changes in collision claim frequency and severity, respectively. If all three crash avoidance technologies were equipped on all light-duty vehicles, this would provide a lower bound annual benefit of about $18 billion with private insurers, households, and third-parties receiving annual benefits of about $2.9, $1.4, and $0.78 billion, respectively, from prevented and less severe crashes. Most of the benefit can be attributed to prevented crashes that accounts for almost 98% of the total benefit although

a very small percentage of crashes are assumed to be prevented as opposed to made less severe. With 2015 pricing safety options, the total annual cost to purchase all three technologies for the entire light-duty vehicle fleet would be about $13 billion-resulting in an annual net benefit of approximately $4 billion. This positive net benefit suggests that the universal adoption of the technologies would be beneficial from an economic perspective. Since the annual cost to purchase the crash avoidance technologies would come from household expenditures, all benefits to private insurers, third-parties, and public revenue sources should be realized when only considering technology purchasing costs.

If all three technologies could prevent all crashes in their respective target crash populations this would provide an upper bound annual benefit of about $214 billion. Of the three crash avoidance technologies examined in this paper, FCW could provide the greatest annual benefit. This technology could provide an upper bound annual benefit of up to $129 billion due to the relatively large number of crashes this technology addresses. At 2015 technology costs, the upper bound annual net-benefit is approximately $202 billion. According to the GES and FARS datasets there are about 178,000 car-pedestrian and pedalcyclist crashes that occurred in 2012. While these crashes were not included in this analysis, FCW could have considerable impacts on the frequency and severity of these crashes, resulting in higher economic benefits, which further supports the case that these technologies would provide a benefit if equipped on all vehicles.

References

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