SOCIETAL BENEFIT OF AUTOMATIC EMERGENCY BRAKING AND LANE DEPARTURE WARNING SYSTEMS IN LARGE TRUCKS

Jeffrey S. Hickman
Matthew Camden
Alejandra Medina-Flintsch
Richard J. Hanowski
Virginia Tech Transportation Institute
U.S.A.

Brian Tefft, B.[2]
AAA Foundation for Traffic Safety, U.S.A.

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ABSTRACT

The objective of this study was to provide scientifically-based estimates of the societal benefits and costs of two large truck advanced driver assistance systems (ADASs): automatic emergency braking (AEB) and lane departure warning (LDW). For each technology, benefit-cost analyses (BCA) were performed for installing the technology on all large trucks (including retrofitting old trucks) and for equipping new large trucks only, and were performed for equipping only single-unit trucks, only combination-unit trucks, and all large trucks. Sensitivity analyses examined three cost estimates, two estimates of system efficacy, and three discount rates. Equipping trucks with LDW systems were found cost-effective under almost all scenarios examined. Results for AEB were mixed. Only the low cost estimate was cost effective for all large trucks regardless of efficacy rate.

BACKGROUND

Recent advances in large truck advanced driver assistance systems (ADASs) have shown promise to mitigate risky driving behaviors or errors, which in turn help prevent large truck crashes. ADASs may use sensors or alerts to warn a driver of a possible collision, 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, or improve driver and fleet management. Two of these large truck ADASs include automatic emergency braking (AEB) systems and lane departure warning (LDW) systems,

AEB systems combine a forward-looking sensor, driver alerts, and automatic vehicle braking. These systems are designed to reduce or prevent rear-end collisions in which the large truck strikes another vehicle (and, to a lesser extent, head-on collisions). LDW systems are vision-based, in-vehicle electronic systems that monitor the vehicle's position within the roadway. Based on lane line markings, the LDW system warns a driver if the vehicle deviates or is about to unintentionally deviate outside the lane line. LDW systems are designed to prevent single vehicle roadway departures, sideswipes, opposite sideswipes, and to a lesser extent, head-on crashes.

Although these large truck ADAS may be effective at preventing large truck crashes, there is limited published data on whether they are cost effective. Despite advancements in the effectiveness of these systems, widespread adoption across the transportation industry is slow. Cost effectiveness data is critical for ADAS as this information may increase industry adoption rates and/or government regulators in mandating their use.

Project Objective

The objective of this project was to provide scientifically-based estimates of the societal benefits and costs (i.e., the impacts an ADAS may have across the entire U.S. society if implemented) of two large truck ADASs, including: AEB systems and LDW systems. To accomplish this objective an Expert Advisory Panel informed cost and benefit estimations for these ADASs so a benefit-cost analysis (BCA) could be performed.

METHODS

An Expert Advisory Panel was held on May 17, 2017. This Advisory Panel consisted of six individuals representing various aspects of the trucking industry, including a representative from a commercial motor vehicle carrier, a trucking insurance company, the Federal Motor Carrier Safety Administration (FMCSA), the National Highway Traffic Safety Administration (NHTSA), an ADAS technology vendor, and an industry safety consultant. The purpose of this meeting was to identify the appropriate efficacy rates and costs for each ADAS and the crash types that may be mitigated or prevented by each of the ADASs. When determining the recommended efficacy rates and cost associated with ADAS, the Advisory Panel prioritized recent research, real-world studies, generation of the technology, Federal regulations, efficacy/cost estimates from the U.S. (due to differences in roadway infrastructure, safety culture, and crash rates), and crash reductions for specific crash types (compared to crash reductions to all large truck crashes). Additionally, the Advisory Panel was conservative in their efficacy estimates. Following this discussion, upper- and lower-bound efficacy rates and low, average, and high costs were selected for each of the two ADAS (Table 1). The efficacy rates selected by the Expert Panel were applied only to the relevant crash types.

Table 1. Advisory Panel Recommended Relevant Crash Types, Efficacy Rates, and Cost

ADAS	Relevant Crash Types	Efficacy Rates	Costs
AEB	Large truck striking rear-end crashes	16% and 28%(1)	\$500, \$2,500, \$3,000(2-4)
LDW.	Single vehicle roadway departures, sideswipes, opposite direction sideswipes, and head-on collisions	30% and 47.8%(3,5)	\$500, \$1,000, \$1,200(3,6-8)

Benefit Cost Analysis Methods

The BCA followed conventional methods used in similar studies to estimate the societal benefits and costs of implementing ADASs in the trucking industry [1-4]. Societal benefits and costs associated with a reduction in crashes with each ADAS were compared to the costs of deploying each ADAS across the entire U.S. fleet of large trucks over an analysis period of 20 years starting in 2018. The benefits included medical-related costs, emergency response service costs, property damage, lost productivity from roadway congestion, and monetized value of quality-adjusted-life-years lost. Costs considered in this study included the purchase and installation costs associated with the ADAS's hardware, maintenance costs of the ADAS, replacement costs of the ADAS, and costs associated with training drivers to use the ADAS, including driver coaching when applicable.

All costs were calculated using information provided by FMCSA (crash costs), the Bureau of Labor Statistics (training costs), costs provided by carriers and technology providers (hardware costs and training requirements), Ricardo's [5] cost and weight analysis, and the Federal Highway Administration, NHTSA, and the Department of Energy (large truck population, large truck population entering the market, vehicle miles traveled, and vehicle age).

To assess the crash reductions (and their associated costs) of each ADAS, national crash databases were used to identify the target population for each ADAS. These crash databases included the Fatality Analysis Reporting System (FARS) and the General Estimates System (GES). The FARS database was used to determine the number of fatal crashes and their associated fatalities and injuries, and the GES database was used as an estimation for injury and property damage only (PDO) crashes. The GES database also was used to estimate the number of injuries as a result of injury crashes. Queries were developed for each ADAS and information was extracted for different vehicle types for a period of 6 years (2010 to 2015).

When filtering the GES and FARS crashes, the research team carefully considered the scenarios where each ADAS could have mitigated or prevented the crash. Specifically, only rear-end crashes where the large truck struck another vehicle were selected for AEB; all large truck road departures, sideswipes, opposite sideswipes, and head-on crashes were selected for LDW. Additionally, the research team used the following GES/FARS variables to further limit crashes that may have been prevented by each ADAS: pre-event movement, critical event, and first harmful event. Finally, all crashes that involved the use of alcohol or drugs by the large truck driver were eliminated.

Two BCAs were performed for each ADAS. The first analyses included retrofitting the entire U.S. fleet of large trucks with the ADAS. This approach assumed all new trucks added to the fleet are equipped with the ADAS and old trucks are retrofitted with the ADAS. These analyses represents the most benefits, but also the largest costs. The second analyses were an annual incremental costs analysis. This approach assumed all new trucks will be equipped with the ADAS (staring in 2018) and no old trucks are retrofitted. Societal benefits were assessed over the life of the truck for both analyses.

Additionally, analyses were performed on different types of large trucks. The first analysis included all class 7 and 8 trucks (gross vehicle weight rating greater than 26,000 pounds). The second was performed only using class 7 and 8 combination unit trucks (CUTs). The third analysis used class 7 and 8 single unit trucks (SUTs). Finally, separate analyses were performed for each ADAS to account for the rate of monetary discount, in the present value, of the cost and benefits in any future year. Following guidance from the Office of Management and Budget [6] analyses were performed using a 0%, 3%, and 7% discount rate.

RESULTS

The BCA results for each of the ADASs are presented below.

Automatic Emergency Braking Systems

AEB systems were evaluated using a low and high efficacy rate (16% and 28%, respectively) and a low, average, and high cost ($500, $2,500, and $3,000, respectively). Table 2 shows the benefit cost ratios (BCRs) for AEB systems when equipping all trucks (new and old). The analyses with a BCR greater than 1.00 indicate the benefits outweigh the costs (highlighted cells in Table 2). For example, the third row in Table 2 shows the results for all large trucks using a high efficacy rate for AEB systems. When the costs of AEB systems are average and the discount rate is 0%, the estimated costs of AEB systems are 9% greater than the estimated benefits. However, when the costs of AEB systems are low and the discount rate is 0%, the estimated benefits of AEB systems are 3.75 times as great as the estimated costs. Overall, only the low cost estimate was found to be cost effective.

Table 2. BCRs for AEB Systems Installed on New and Old Trucks by Vehicle Type, Efficacy Rate, Cost, and Discount Rate

	Low Cost ($500)			Average Cost ($2,500)			High Cost ($3,000)		
	0%	3%	7%	0%	3%	7%	0%	3%	7%
All Large trucks – 28% Efficacy	3.75	3.58	3.37	0.91	0.87	0.82	0.76	0.73	0.69
All Large trucks – 16% Efficacy	2.14	2.05	1.93	0.52	0.50	0.47	0.44	0.42	0.39
Only CUTs – 28% Efficacy	4.11	3.94	3.72	0.99	0.95	0.90	0.83	0.80	0.76
Only CUTs – 16% Efficacy	2.35	2.25	2.13	0.56	0.54	0.52	0.47	0.46	0.43
Only SUTs – 28% Efficacy	3.08	2.92	2.72	0.75	0.72	0.67	0.63	0.60	0.56
Only SUTs – 16% Efficacy	1.76	1.67	1.56	0.43	0.41	0.38	0.36	0.34	0.32

Table 3 shows the BCRs for AEB systems when only equipping new trucks. As shown in Table 3, a low-cost AEB system was cost effective with a 26% efficacy rate. However, the $2,500 and $3,000 AEB system were also cost effective with a 28% efficacy rate.

Table 3. BCRs for AEB Systems Installed on New Trucks Only by Vehicle Type, Efficacy Rate, Cost, and Discount Rate

	Low Cost ($500)			Average Cost ($2,500)			High Cost ($3,000)		
	0%	3%	7%	0%	3%	7%	0%	3%	7%
All Large trucks – 28% Efficacy	6.09	5.67	5.27	1.62	1.49	1.36	1.37	1.26	1.15
All Large trucks – 16% Efficacy	3.48	3.24	3.01	0.92	0.85	0.78	0.78	0.72	0.66
Only CUTs – 28% Efficacy	6.41	5.97	5.54	1.70	1.57	1.43	1.44	1.32	1.21
Only CUTs – 16% Efficacy	3.66	3.41	3.17	0.97	0.89	0.82	0.82	0.76	0.69
Only SUTs – 28% Efficacy	6.09	5.67	5.27	1.62	1.49	1.36	1.21	1.12	1.02
Only SUTs – 16% Efficacy	3.48	3.24	3.01	0.92	0.85	0.78	0.69	0.64	0.58

Lane Departure Warning Systems

LDW systems were evaluated using a low and high efficacy rate (30% and 47.8%, respectively) and a low, average, and high cost ($500, $1,000, and $1,200, respectively). Table 4 shows the BCRs for LDW systems when equipping all trucks (new and old). The results showed that equipping all large trucks or all CUTs with LDW were cost effective regardless of cost, efficacy rate, or discount rate. Additionally, equipping all SUTs with LDW was cost effective with a high efficacy rate regardless of cost or discount rate. However, LDW was only cost effective for SUTs with a low cost.

Table 4. BCRs for LDW Systems Installed on All Trucks by Vehicle Type, Efficacy Rate, Cost, and Discount Rate

	Low Cost ($500)			Average Cost ($1,000)			High Cost ($1,200)		
	0%	3%	7%	0%	3%	7%	0%	3%	7%
All Large trucks – 47.8% Efficacy	4.11	3.92	3.69	2.30	2.20	2.08	1.96	1.88	1.77
All Large trucks – 30% Efficacy	2.62	2.50	2.36	1.47	1.41	1.33	1.25	1.20	1.13
Only CUTs – 47.8% Efficacy	4.83	4.63	4.38	2.70	2.59	2.46	2.29	2.21	2.09
Only CUTs – 30% Efficacy	3.08	2.96	2.79	1.72	1.66	1.57	1.46	1.41	1.33
Only SUTs – 47.8% Efficacy	2.74	2.60	2.43	1.55	1.47	1.37	1.32	1.25	1.17
Only SUTs – 30% Efficacy	1.75	1.66	1.55	0.99	0.94	0.88	0.84	0.80	0.75

Table 5 shows the BCRs for LDW systems when only equipping new trucks. As shown in Table 5, low-, average-, and high-cost LDW systems were cost effective for the lower and upper efficacy rate with all truck types.

Table 5. BCRs for LDW Systems Installed on New Trucks Only by Vehicle Type, Efficacy Rate, Cost, and Discount Rate

	Low Cost ($500)			Average Cost ($1,000)			High Cost ($1,200)		
	0%	3%	7%	0%	3%	7%	0%	3%	7%
All Large trucks – 47.8% Efficacy	6.67	6.21	5.77	3.94	3.65	3.36	3.39	3.13	2.87
All Large trucks – 30% Efficacy	4.26	3.96	3.68	2.52	2.33	2.14	2.16	2.00	1.83

	Low Cost ($500)			Average Cost ($1,000)			High Cost ($1,200)		
	0%	3%	7%	0%	3%	7%	0%	3%	7%
Only CUTs – 47.8% Efficacy	7.53	7.02	6.52	4.45	4.12	3.79	3.83	3.54	3.25
Only CUTs – 30% Efficacy	4.81	4.48	4.16	2.84	2.63	2.42	2.44	2.26	2.07
Only SUTs – 47.8% Efficacy	4.83	4.50	4.18	2.85	2.64	2.43	2.45	2.27	2.08
Only SUTs – 30% Efficacy	3.08	2.87	2.67	1.82	1.69	1.55	1.57	1.45	1.33

DISCUSSION

The current study used efficacy rates from previously published research and identified crashes that may have been prevented through the deployment of an ADAS. Crashes were identified using 2010 to 2015 GES and FARS datasets. BCAs were performed using varying efficacy rates (low and high), vehicle types (all large trucks, only CUTs, and only SUTs), costs (low, average, and high), and discount rates (0%, 3%, and 7%).

Automatic Emergency Braking System Conclusions

The results showed the current pricing/efficacy rate used in this study did not always suggest that AEB systems were cost effective. Only a $500 AEB system was found to consistently be cost effective regardless of which trucks were equipped with the system. Average and high-cost systems were only found to be cost effective occasionally. Additionally, retrofitting old large trucks with AEB systems typically was not cost effective. These results provide insight into the feasibility of government regulation for large truck AEB systems. There was not a strong case for government regulation requiring AEB systems for the entire U.S. fleet of large trucks given the cost/efficacy rates used in this study. However, the analyses showed AEB systems on new CUTs were cost effective with a high efficacy rate regardless of cost. If the cost and efficacy of AEB systems can be maintained (or improved from) at $2,500 and 28%, respectively, regulation may be appropriate.

Lane Departure Warning System Conclusions

The results strongly support the cost effectiveness of LDW systems for all large trucks. Regardless of cost and efficacy rate, LDW systems were shown to be cost effective. These results were likely due to: (1) the relatively low cost of LDW systems compared to other ADASs, and (2) the large number/severity of roadway departures, sideswipes, opposite sideswipes, and head-on crashes that could be prevented with LDW systems. As with the other ADASs, cost effectiveness was higher with regulations only for new large trucks. However, these results would support LDW system regulations for both all trucks (retrofitting and original equipment manufacturer installed) and only new large trucks. Mandating LDW on all large trucks (both new and old) would result in the largest benefits in crashes prevented.

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