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Crash avoidance potential of four passenger vehicle technologies

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ABSTRACT

Objectives: The objective was to update estimates of maximum potential crash reductions in the United States associated with each of four crash avoidance technologies: side view assist, forward collision warning/mitigation, lane departure warning/prevention, and adaptive headlights. Compared with previous estimates (Farmer, 2008), estimates in this study attempted to account for known limitations of current systems.

Methods: Crash records were extracted from the 2004–08 files of the National Automotive Sampling System General Estimates System (NASS GES) and the Fatality Analysis Reporting System (FARS). Crash descriptors such as vehicle damage location, road characteristics, time of day, and precrash maneuvers were reviewed to determine whether the information or action provided by each technology potentially could have prevented or mitigated the crash.

Results: Of the four crash avoidance technologies, forward collision warning/mitigation had the greatest potential for preventing crashes of any severity; the technology is potentially applicable to 1.2 million crashes in the United States each year, including 66,000 serious and moderate injury crashes and 879 fatal crashes. Lane departure warning/prevention systems appeared relevant to 179,000 crashes per year. Side view assist and adaptive headlights could prevent 395,000 and 142,000 crashes per year, respectively. Lane departure warning/prevention was relevant to the most fatal crashes, up to 7500 fatal crashes per year. A combination of all four current technologies potentially could prevent or mitigate (without double counting) up to 1,866,000 crashes each year, including 149,000 serious and moderate injury crashes and 10,238 fatal crashes. If forward collision warning were extended to detect objects, pedestrians, and bicyclists, it would be relevant to an additional 3868 unique fatal crashes.

Conclusions: There is great potential effectiveness for vehicle-based crash avoidance systems. However, it is yet to be determined how drivers will interact with the systems. The actual effectiveness of these systems will not be known until sufficient real-world experience has been gained.

1. Introduction

Improvements in vehicle crashworthiness during the past decades have increased occupant survivability when crashes occur (Farmer and Lund, 2006), and recent automobile designs are focusing on ways to avoid crashes altogether. Automakers are refining advanced technologies designed to prevent or mitigate crashes and introducing them into a growing number of passenger vehicle models. Electronic stability control, an early example of crash avoidance technologies, already has proven highly effective, with an estimated 49% reduction in fatal single-vehicle crash risk and an estimated 20% reduction in fatal multiple-vehicle crash risk for equipped cars and SUVs (Farmer, 2010). More recently, technologies such as forward collision warning, lane departure warning, side view assist, and adaptive headlights have been introduced in the passenger vehicle fleet, primarily in luxury vehicles.

Several researchers have reported on the number of crashes that may be prevented by crash avoidance technologies. For example, prior to commercial availability of these systems, the National Highway Traffic Safety Administration (NHTSA) predicted these systems would prevent as many as 791,000 rear-end, 90,000 lane change, and 297,000 road departure crashes in the United States each year (NHTSA, 1996). More recently, Pomerleau et al. (1999) predicted warning systems could prevent 336,000 road departure crashes per year. A 2005 study concluded that warning systems could prevent nearly 14,000 lane change and road departure crashes in the European Union (Abele et al., 2005). Kuehn et al. (2009) used insurance collision claims data coupled with human factors research and determined as many as 24,000 rear-end, 2000 lane change, and 3000 road departure crashes could be prevented in Germany if all vehicles were equipped with several crash avoidance technologies. In a previous study by the Insurance Institute for Highway Safety, Farmer (2008) estimated the maximum potential

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of five crash avoidance technologies — side view assist, forward collision warning/mitigation, emergency brake assist, lane departure warning, and adaptive headlights — using crash records from the 2002–06 files of the National Automotive Sampling System General Estimates System (NASS GES) and Fatality Analysis Reporting System (FARS). Crash types that possibly could have been prevented or mitigated by a crash avoidance system were counted as relevant for that technology. The study was meant to address not only current technologies but also systems that may be available in the future.

Current technologies may not function in all circumstance because of limitations inherent in their designs. For example, lane departure warning systems use visible lane markers to track vehicle position within the lane. If lane markers are not visible because the roadway is covered by snow, the system will not work. Several systems use sensors that may not reliably detect other vehicle movements in rain, snow, sleet, or fog. The purpose of the present research is to refine the initial maximum potential crash reduction estimates, accounting for limitations of currently or imminently available systems. It is important to note that the crash avoidance landscape is changing rapidly, and limitations of current systems may not be limitations of future systems. In addition, the actual capabilities of the technologies may extend beyond what is currently described by vehicle manufacturers. The current study examined four crash avoidance technologies: side view assist for intentional lane changing, forward collision warning/mitigation, lane departure warning/prevention, and adaptive headlights. Crash reduction estimates for brake assist systems were not included in the updated estimates because rudimentary brake assist technologies have been available on passenger vehicles for many years. As a result, there is large market penetration of these systems, and many vehicles in the most recent crash files already may be equipped. Crashes relevant to more advanced brake assist technologies and newer autonomous braking systems are addressed by forward collision warning estimates.

Crash counts are estimates of the maximum potential applicability of current technologies. Although these estimates account for relevant crash types and known limitations of current crash avoidance systems, they do not account for potential reductions in effectiveness due to driver interactions with the systems. That is, the estimates provide the total number of crashes that may be prevented or mitigated if the systems were on all vehicles, were 100% effective in alerting drivers and drivers had the appropriate responses 100% of the time. Actual effects depend on how drivers accept the technologies and respond to the information provided by the systems and/or the actions taken by the systems. Not all drivers will react appropriately. Drivers may be overwhelmed or annoyed by the warnings, particularly if vehicles are equipped with multiple technologies, allowing for potential simultaneous warnings. If drivers find the systems annoying or not useful, they may disable the systems, rendering them ineffective. Braitman et al. (2009) surveyed drivers of vehicles with the four crash avoidance technologies described herein and reported that, despite some annoyance by the warnings, the majority of drivers left the systems turned on most of the time. Reported use was lowest for the system that required drivers to turn it on (lane departure prevention) rather than for systems that automatically turned on by default.

Several researchers have reported on the effectiveness of these systems, taking into account driver interaction with the systems, as found in field operational tests, simulator studies, and other experimental studies. Field tests of a prototype of a road departure warning system showed mixed results (Wilson et al., 2007). The system worked well consistently on roads with clear lane markings but only 36% of the time on nonfreeways. Taking this into account, the authors estimated the system could reduce road departure crashes in the United States by 5000 to 41,000 per year. A prototype forward collision warning system was field-tested by 66 drivers for 4 weeks each (Najm et al., 2006). Based on the number of near crash scenarios identified, the system was projected to reduce rear-end collision rates by 10%. Sugimoto and Sauer (2005) estimated that a system with automatic braking in addition to a warning could prevent 38% of rear-end collisions, while Coelingh et al. (2007) predicted a 50% reduction.

Crash avoidance technologies, particularly forward collision warning systems, show promise in mitigating crash severity even if the crash is not avoided entirely. Schittenhelm (2009) analyzed the repair history of certain Mercedes S-Class vehicles with and without Distronic Plus, an active cruise control system that incorporates brake assist and forward collision warning/mitigation technologies. The vehicles with Distronic Plus showed a 5% reduction in rate of repairs for the front bumper alone, damage in the least severe crashes; a 15% reduction in rate of repairs for the front bumper and cross member, damage in mid-severity crashes; and a 25% reduction in rate of repairs for the front bumper, cross member, and longitudinal member, damage in the most severe crashes.

The ultimate effect of crash avoidance technologies also depends on whether they fundamentally alter the driving task or driver behavior. Braitman et al. (2009) found both negative and positive effects of crash avoidance technologies on driver behavior. Nine percent of drivers with side view assist systems said they change lanes more often, a small percentage of drivers with forward collision warning reported they look away from the road more often (5%) or follow the vehicle ahead more closely (2%), and drivers with active headlights reported a greater willingness to drive at night (40%) and to drive faster (18%). However, almost half of the drivers with forward collision warning said they follow the vehicle ahead less closely and, among owners with lane departure warning and/or prevention systems, 54–64% reported using their turn signals more often and 67–71% said they drift from travel lanes less often.

2. Methods

Data were extracted from two national crash databases maintained by the National Highway Traffic Safety Administration (NHTSA). NASS GES contains information from annual probability samples of police-reported crashes in the United States. Approximately 57,000 crashes are sampled each year. When each case is weighted by the inverse of its selection probability, the yearly sample is representative of about 6 million crashes nationwide (NHTSA, 2008). FARS is an annual census of crashes that occur on public roads and result in the death of a vehicle occupant or other involved party within 30 days of the crash.

All passenger vehicle records in the 2004–08 NASS GES and FARS files (vehicle body types 1–49) were merged with the corresponding crash records. Records in GES were weighted by their case weights to produce national estimates. Crashes in GES with maximum injury severity coded as incapacitating (A) or nonincapacitating (B) were classified as severe or moderate injury crashes. To account for missing data in the crash files, imputed data were used whenever available in the GES files. Imputing data involves replacing missing values with likely values, in a statistically appropriate manner, and then analyses are conducted on the augmented data set.

The first step was to assign each crash to one of nine general crash types. Classification was hierarchical, so any crash with characteristics of more than one category was assigned to the earliest category in the following list: changing lanes, angle, front-to-rear, single-vehicle, head-on, other front-to-front, sideswipe same direction, sideswipe opposite direction, and other. In other words, changing lanes took precedence over all other categories. This categorization implied no meaning other than providing a useful starting point for identifying relevant crashes for each technology.