Crash Prevention and Safety

ITS Benefits, Costs, and Lessons Learned: 2017 Update Report

U.S. Department of Transportation

Crash Prevention and Safety

Road Geometry Warning
Highway-Rail Crossing Warning
Intersection Collision Warning
Pedestrian Safety
Bicycle Warning
Animal Warning
Collision Avoidance
Collision Notification
Weather Warning
Work Zone Warning

Highlights

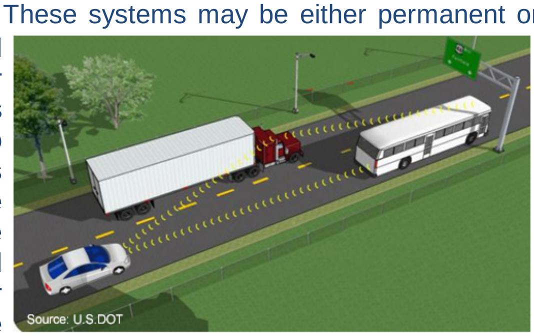
- The new wave of crash prevention and safety strategies includes the integration of vehicle and infrastructure safety systems and implementation of connected vehicle technologies for safety applications.
- Crash avoidance technologies have shown to decrease crashes and can reduce occurrences of driver injury and fatalities by up to 57 percent.

Introduction

This factsheet is based on past evaluation data contained in the ITS Knowledge Resources database at: www.itskrs.its.dot.gov. The database is maintained by the U.S. DOT's ITS JPO Evaluation Program to support informed decision making regarding ITS investments by tracking the effectiveness of deployed ITS. The factsheet presents benefits, costs and lessons learned from past evaluations of ITS projects.

A major goal of the ITS program is to improve safety and reduce risk for road users including pedestrians, cyclists, operators, and occupants of all vehicles who travel along our roadways. After many years of declining motor vehicle crashes and fatalities on the Nation's roadways, 2012 showed a 4 percent increase in fatalities. Since then, there been slight decreases in fatalities, although the number of fatalities per hundred million vehicle miles of travel (VMT) has stayed relatively constant. A statistical projection of traffic fatalities for the first 9 months of 2016 shows an estimated 27,875 people died in motor vehicle traffic crashes. This represents an increase of about 8% as compared to the 25,808 fatalities that were reported to have occurred in the first 9 months of 2015. [1]

Crash prevention and safety systems detect unsafe conditions and provide warnings to travelers to take action to avoid crashes. These systems provide alerts for traffic approaching dangerous curves, off ramps, restricted overpasses, highway-rail crossings, high-volume intersections, work zones, adverse weather conditions, and also provide warnings of the presence of pedestrians, bicyclists, and even animals on the roadway. Crash prevention and safety systems typically employ sensors to monitor the speed and characteristics of approaching vehicles and frequently also include environmental sensors to monitor roadway conditions and visibility. These systems may be either permanent or temporary. Some systems provide a general warning of the recommended speed for prevailing roadway conditions. Other systems provide a specific warning by taking into account the particular vehicles characteristics (truck or car) and a calculation of the recommended speed for the particular vehicle based on conditions. In some cases, manual systems are employed, where pedestrians or bicyclists manually set the system to provide warnings of their presence to travelers; however these systems are being replaced with automated systems with the increasing implementation of connected vehicle technologies. With the introduction of connected vehicle safety applications, crash prevention and safety systems are also moving from passive driver warning systems, to active driver assistance systems where the vehicle can automatically react to other vehicles or road sensors during hazardous conditions.



Intersection Collision Warning Systems: Intersection collision warning systems use sensors to monitor traffic approaching dangerous intersections and warn vehicles of approaching cross traffic, using roadside infrastructure, in-vehicle systems, or some combination of the two. The newer approaches to intersection collision warning systems provide information to drivers on proper maneuvers (gap acceptance assistance) and warn drivers of right-of-way violations at intersections. The warnings may include the driver's vehicle violating traffic control signs or signals or of another vehicle violating, or about to violate, the subject vehicle's right-of-way. Specific examples are provided below:

- Left Turn Assist: Warnings given to driver via an in-vehicle system when trying to make a left turn that may be visually blocked by another car or object. Warnings can alert the driver that a left turn should not be attempted.
- Traffic Control Violation Warning: Warnings given to drivers via in-vehicle systems if it is determined the driver may violate a red light or other traffic control device.
- Stop Sign Gap Assist: Information provided to drivers while stopped at a stop sign where only the minor road has stop signs. The driver receives information of any danger to the vehicle proceeding through the intersection from vehicles approaching on the cross street.

Collision Avoidance Systems: To improve the ability of drivers to avoid accidents, vehicle-mounted collision warning systems (CWS) continue to be tested and deployed. These applications use a variety of sensors to monitor the vehicles surroundings and alert the driver of conditions that could lead to a collision. Examples include forward collision warning, obstacle detection systems, rear impact collision warning, "do not pass" warnings, and road departure warning systems.

Collision Notification: In an effort to improve response times and save lives, collision notification systems have been designed to detect and report the location and severity of incidents to agencies and services responsible for coordinating appropriate emergency response actions. These systems can be activated manually (Mayday), or automatically with automatic collision notification (ACN), and advanced systems may transmit information on the type of crash, number of passengers, and the likelihood of injuries.

Benefits

Crash Prevention and Safety strategies include collision avoidance systems and systems that warn drivers of potential road hazards. These systems have demonstrated success in detecting potential conflicts and warning motorists of crash potential. Evaluations of these systems find reduction in road crashes, injuries and fatalities as summarized in Table 1.

Table 1: Selected Benefits for Crash Prevention and Safety Strategies.

Categories	Selected Findings
Collision Avoidance	A Korean study finds that Automatic Crash Information Notification Systems would reduce freeway fatalities by 11.8 to 18.1 percent. (2013-00864)
Collision Avoidance	Electronic Stability Control (ESC) systems can reduce the risk of fatal crashes by 33 percent. (2013-00861)
Collision Avoidance for Trucks	Forward collision warning systems have potential to prevent 23.8 percent of crashes involving large trucks. (2012-00811)
Collision Avoidance for Transit Vehicles	The camera-based system with a regular angle lens reduced 43 percent of blind zones, and wide-angle camera systems were able to entirely eliminate blind zones. (2013-00853)
Pedestrian Safety	In Tucson, Arizona, installation of High-Intensity Activated Crosswalk (HAWK) pedestrian beacons showed 69 percent reduction in crashes involving pedestrians. (2013-00848)
Animal Detection System	In Montana, an animal detection system with the warning lights activated resulted in 1.52 mi/h lower vehicle speeds (compared to warning lights off) for passenger cars and pick-ups.(2012-00752)

In-vehicle active and passive safety technologies have also shown to provide significant benefits to road users. The most significant findings are that in-vehicle technologies, including automated braking systems, have the ability to significantly reduce the injury and fatalities due to collisions. Table 2 highlights some of these findings.

Table 2: Selected Benefits for In-vehicle Safety Technologies.

Categories	Selected Findings
Automated Braking System	In 2011, NHTSA evaluated an Advanced Collision Mitigation Braking System (A-CMBS) designed with forward sensing radar, an on-board electronic control unit, and sensors to monitor vehicle speed, brake pressure, steering angle, and yaw to predict and warn drivers of impending collisions, and automatically implement countermeasures to avoid or mitigate collisions. The report found that light vehicles that automatically activate in-vehicle alerts, seat belt tensioners, and braking systems can reduce fatalities by 3.7 percent. (2013-00833)
Automated Braking System	In-vehicle technologies that use automated braking to prevent rear-end collisions can reduce drivers injured by 19 to 57 percent. (2013-00832)
Automated Braking System	Advanced emergency braking systems in passenger vehicles have potential benefit-cost ratios ranging from 0.07 to 2.78. (2012-00815)
In-vehicle Safety System	A literature review of in-vehicle safety systems in the United States and New South Wales, Australia found that active and passive in-vehicle safety technologies are expected to decrease fatalities up to 16 percent. (2013-00827)

Figure 1 shows ranges of benefits for select entries in the ITS Knowledge Resource database at: http://www.itsknowledgeresources.its.dot.gov/. Benefits of collision notification and avoidance system include reduction in fatalities and injury to drivers.

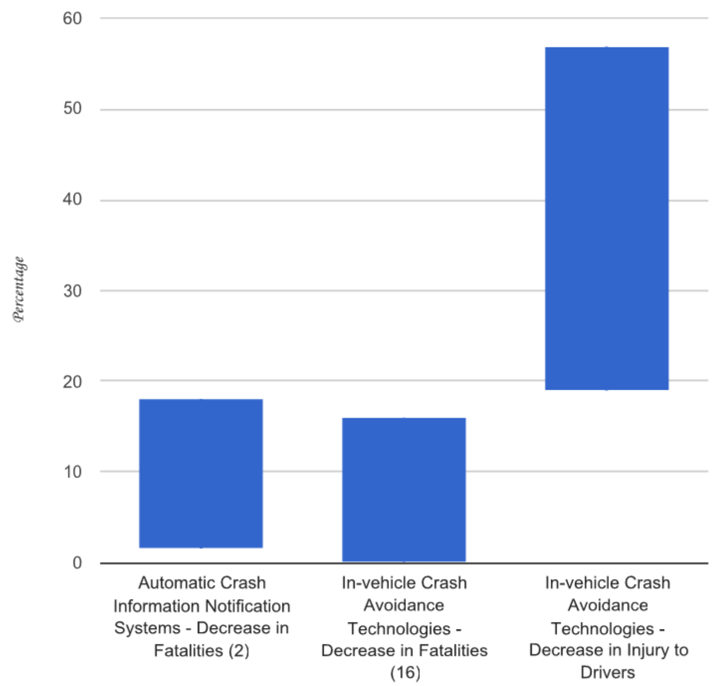


Figure 1: Range of Benefits for Crash Avoidance Technologies (Source: ITS Knowledge Resources).

The online versions of the factsheets feature interactive graphs that contain all the data points included in the ranges. Here, each metric has a number after the text, representing the number of data points used to create the range; no number means only there was only one data point.

Several crash warning systems have also shown significant benefits in reducing overall number of crashes**.** Figure 2 shows the ranges of these benefits.

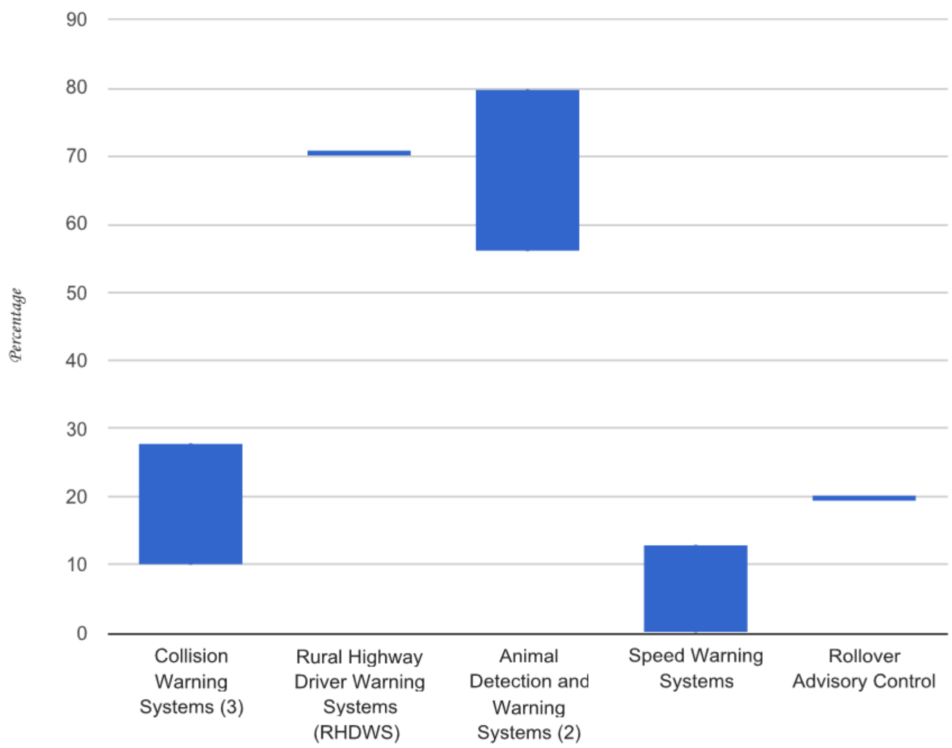
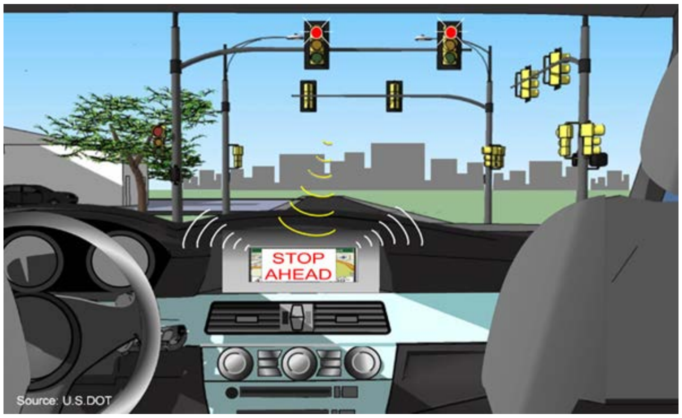


Figure 2: Range of Crash Reduction Benefits from Collision Warning Systems (Source: ITS Knowledge Resources).

As connected vehicle technologies are just now being developed and tested, few evaluations are available. However, driver acceptance clinics were conducted at six different cities in the United States to assess how motorists respond to connected vehicle technologies and benefit from in-vehicle alerts and warnings. The preliminary findings showed that 91 percent of volunteer drivers that tested vehicle-to-vehicle (V2V) communications safety features indicated they would like to have these technologies on their personal vehicle (2012-00785).

Additionally, a European study evaluated the potential benefits and costs of V2V and vehicle-to-infrastructure (V2I) technologies. This study concluded that V2V applications can have positive benefit-cost ratios at fleet penetration rates above 6.1 percent, whereas V2I technologies require a greater market share (2013-00842).

Costs



The ITS Knowledge Resources database provides a variety of system costs for crash prevention and safety strategies that range from individual in-vehicle collision avoidance systems to estimates of nationwide implementations of connected vehicle environments.

The database includes several recent cost estimates for in-vehicle collision avoidance systems shown in Table 3. Delphi study techniques, using independent estimates from multiple industry experts and multiple rounds to achieve consensus, were used to forecast the estimated costs for future years.

Table 3: System Costs for Crash Prevention Systems.

In-vehicle collision avoidance systems	Year	System Costs
Advanced Emergency Brake System in the UK (2012-00275)	2011	$334 - $1,337
Side collision warning system (Blind Spot Warning) (2013-00287)	2010	$760 to $2,000
Advanced Emergency Brake Systems with pedestrian detection in the UK (2012-00275)	2009	$1,499 - $2,249
Lane Departure Warning Systems in the UK (2012-00275)	2009	$457 - $750
Cost to Vehicle Manufacturers for Embedded On-board DSRC equipment (2013-00288)	2017	$175
Cost to Vehicle Manufacturers for Embedded On-board DSRC equipment (2013-00288)	2022	$75
Cost Added to Base Vehicle Price for DSRC equipment (2013-00288)	2017	$350
Cost Added to Base Vehicle Price for DSRC equipment (2013-00288)	2022	$300
Aftermarket DSRC equipment (2013-00288)	2017	$200
Aftermarket DSRC equipment (2013-00288)	2022	$75

Lessons Learned

The ITS Knowledge Resources database identifies several lessons learned from crash prevention strategies. A national evaluation of ITS applications presents new approaches to address distracted driving when designing and developing ITS applications (2013-00651).

- **Communicate alerts designed to orient drivers to general traffic conditions ahead, and therefore, make them more attentive to the driving environment to help reduce driver distraction.**
- **Use "geofencing" as an approach to limiting driver distraction.** The geofencing technique attempts to determine which mode the traveler is using in order to allow transit users to continue to receive updates while on the move while preventing them from using the information while driving. It was demonstrated that it is feasible to determine whether a smart phone user is traveling on a transit vehicle versus in a vehicle on a road. Therefore it is possible to provide travel information to smart phone users while minimizing the risk of distraction.
- **Continue to explore avenues for advancements in technology to prevent driver distraction as well as instilling a safety culture mindset to support the goal of a change in driver behavior.** As in-vehicle technology continues to develop, supporting safe driving habits will continue to be a challenge.

Case Study: Minnesota's Cooperative Intersection Collision Avoidance System – Stop Sign Assist (CICAS-SSA)

To help drivers better assess rural highway intersection crossings, the University of Minnesota developed an infrastructure-based Cooperative Intersection Collision Avoidance System - Stop Sign Assist (CICAS-SSA). Using multiple sensors and algorithms to track vehicles moving along a divided highway, the system helps drivers reject small gaps at rural stop controlled intersections. This is done by gathering information and alerting drivers on the secondary rural roads via LED icon-based sign switches (Figure 1) when gaps in the highway traffic are too small to cross safely. The system is based on research findings that show most rural highway intersection crashes are due to drivers failing to stop at a median and crossing an intersection in a single-stage maneuver.

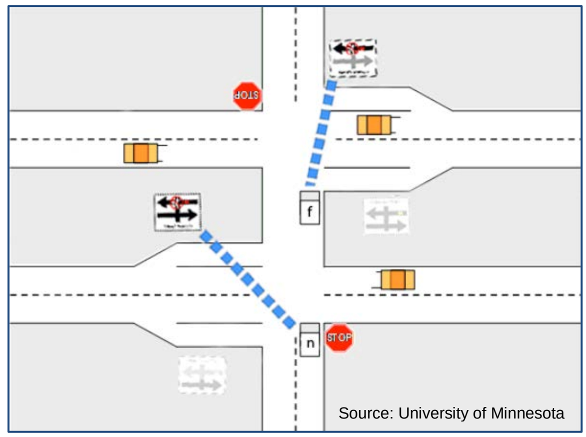
Source: University of Minnesota

In December 2013, a three-year study assessing the long-term effectiveness of the CICAS-SSA system in Minnesota was summarized in Becic and Manser (2013). The study assessed the system's ability to reduce the frequency of collisions at rural stop controlled intersections in which the system was installed (a field operational test (FOT)). The report analyzed the long-term efficacy of the system using:

- A Safety Analysis that compared the frequency of collisions after the installation of the CICAS-SSA system with the established baseline rate of the frequency of crashes at several test intersections. The baseline was determined using Minnesota DOT crash data.
- A Crash Prediction Analysis developed using a crash prediction model that assessed the extent to which the actual frequency of crashes at the tested intersections matched the predictive frequency.

Three Minnesota intersections served as a case study for the traffic-based FOT:

- TH 23 (four-lane divided rural highway) and CSAH 7 (Two-lane road), by Marshall, Minnesota.
- US 52 (four-lane divided rural highway) and CSAH 9 (two-lane road), by Cannon Falls, Minnesota.
- US 169 (four-lane divided rural highway) and CSAH 11 (two-lane road), by Milaca, Minnesota.



Source: University of Minnesota

The results of the study (Becic and Manser (2013)) are in line with findings from previous CICAS-SSA research efforts. Most of these efforts reported either a lack of impact (i.e., drivers' acceptance of critical gaps did not differ between treatment and control conditions) or a beneficial impact in very specific conditions (i.e., limited visibility). This limited impact result may be due to challenges specific to the test intersections (e.g., limited site distance, different roadway configuration, location relative to area).

The study also suggested that highly accident-prone intersections need to be used as case studies in order to ensure sufficient crash data for rigorous research regarding CICAS-SSA.

References

[1] National Highway Traffic Safety Administration. *Traffic Safety Facts.* Early Estimate of Motor Vehicle Traffic Fatalities for the First 9 Months of 2016 January 2017. https://crashstats.nhtsa.dot.gov/Api/Public/ViewPublication/812358.

[2] Becic, E., & Manser, M. (2013). Cooperative Intersection Collision Avoidance System - Stop Sign Assist (CICAS-SSA). Saint Paul: Minnesota Department of Transportation. http://ihub.dot.state.mn.us/its/projects/2011-2015/cicas/trafficbasedfotfinalreport.pdf

[3] "Cooperative Intersection Collision Avoidance System – Stop Sign Assist (CICAS-SSA)" University of Minnesota, ITS Institute. http://www.its.umn.edu/Research/FeaturedStudies/intersections/cicas.html

All other data referenced is available through the ITS Knowledge Resources Database, which can be found at http://www.itsknowledgeresources.its.dot.gov/.