CRASH PREVENTION AND SAFETY

THE FOUR MOST WIDELY ADOPTED CRASH PREVENTION AND SAFETY SYSTEMS ARE CURVE AND RAMP SPEED WARNING, RAIL CROSSING WARNING, AND PEDESTRIAN SAFETY SYSTEMS.

ROADWAYS

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 must travel along a given roadway. On the Nation's roadways, vehicle crashes at horizontal curves and intersections account for approximately 25 percent and 21 percent of fatalities, respectively. Nearly 13 percent of those killed in motor vehicle crashes are pedestrians and bicyclists, and more than 1 percent of crashes occur at highway-rail crossings.[154] Interstates and other freeway ramp curves can be dangerous locations because drivers must perceive the point at which to begin braking and slow down sufficiently to safely negotiate the ramp curve.

Road geometry warning systems warn drivers of potentially dangerous conditions that may cause rollover or run-off-the-road crashes on ramps, curves, or downgrades, and provide overheight warnings at tunnels and overpasses. Highway-rail crossing warning systems can reduce the potential for collisions at railroad crossings including catastrophic crashes involving school buses or hazardous materials carriers. Intersection collision warning systems use sensors to monitor traffic approaching dangerous intersections and warn vehicles of approaching cross-traffic via roadside or in-vehicle displays. Pedestrian safety systems can adjust traffic signal timing to provide an appropriate WALK phase or activate in-pavement lighting or roadside warning messages to alert drivers of pedestrians present. Bicycle warning systems can detect cyclists on narrow stretches of roadway and provide drivers with advanced notice when entering bridges and tunnels. In rural areas, animal warning systems can detect large animals near the roadway, alert travelers, and deter animals from crossing while traffic is present.

In addition to the ITS technologies profiled in this chapter, the Cooperative Intersection Collision Avoidance Systems (CICAS) initiative, a major ITS initiative being conducted by the U.S. DOT has the potential to enhance crash prevention and safety. Through CICAS, the U.S. DOT is working with automotive manufacturers and State and local DOTs to develop and test autonomous-vehicle, autonomous-infrastructure, and cooperative communication systems that can help prevent crashes at intersections. For more information, visit the ITS JPO's Web site: *www.its.dot.gov/cicas.*

Findings

Benefits

Road geometry warning systems can improve safety on highway ramps or curves that experience a high incidence of truck rollovers. Providing truckers with advanced notice of excessive approach speeds can reduce truck speeds by up to 8.3 mi/h. Several years of safety data collected at multiple sites show these systems can eliminate rollover crashes, and the impacts are sustainable. Downhill speed warning systems have also proven effective at mitigating risks to large trucks in areas with steep terrain. These speed advisory systems have decreased truck crashes by up to 13 percent at problem sites in Oregon and Colorado.[155]

A nationwide survey evaluating overheight/overwidth warning systems found that eight states that deployed active infrared light or laser activated warning systems had fewer overheight load strikes on infrastructure components.[156] Although active warning systems were found to be more effective than passive ridged crossbeam structures or overhead suspended chain warning systems, human error was prevalent highlighting the need to thoroughly consider driver perception and compliance prior to deployment.

CRASH PREVENTION AND SAFETY CATEGORIES IN THE ITS KNOWLEDGE RESOURCES

Road Geometry Warning

- Ramp Rollover Warning
- Curve Speed Warning
- Downhill Speed Warning
- Overheight/Overwidth Warning

Highway-Rail Crossing Warning Systems

Intersection Collision Warning

Pedestrian Safety

Bicycle Warning

Animal Warning

DOWNHILL SPEED WARNING SYSTEMS HAVE DECREASED TRUCK CRASHES UP TO 13 PERCENT AT PROBLEM SITES IN OREGON AND COLORADO.

The need to reduce crashes at intersections has fostered considerable research to develop and evaluate cost-effective countermeasures. Initial research suggests that most drivers will respond to intersection collision warning systems and slow or stop appropriately.[157] These systems are currently being designed to transmit warning messages to in-vehicle systems and display warnings on roadside infrastructure.

Table 4 illustrates that evaluations have shown the safety benefits for deployed crash prevention and safety systems. Several evaluations have documented customer satisfaction with road geometry and highway-rail crossing warning systems. A study also indicated mobility, fuel consumption, and emissions improvements through a highway-rail crossing warning system.

Table 4—Crash Prevention and Safety Benefits Summary

	Safety	Mobility	Efficiency	Productivity	Energy and Environment	Customer Satisfaction
Road Geometry Warning	●					●
Highway-Rail Crossing Systems	●	✚			✚	●
Intersection Collision Warning	✚					
Pedestrian Safety	●					
Bicycle Warning						
Animal Warning	●					

● Substantial positive impacts
❍ Negligible impacts
✖ Negative impacts
✚ Positive impacts
✱ Mixed results
blank Not enough data

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Costs

The initial costs of crash prevention and safety systems vary depending on the technology deployed, system configuration, and functionality offered. As part of an evaluation of automated truck rollover warning systems, the Pennsylvania DOT (PennDOT) researched systems in other states. The cost of these systems varied significantly, ranging from $50,000 to $500,000, as did their configurations: invasive and non-invasive detection, weight-based versus simplified speed class algorithms, and system calibrations for warnings.[158]

Based on responses to a nationwide survey of states operating overheight detection systems, the initial costs of active laser or infrared systems vary considerably ranging from $7,000 to $70,000. Although costs data are not widely available, the operations and maintenance (O&M) costs are considered relatively minimal regardless of the type of system deployed ranging from $1,000 to $2,500. The wide variation in capital costs is due to the fact that each system vendor packages its system differently. Some vendors perform the equipment installation and the labor cost is included in the total deployment costs. Also, some vendors select from multiple systems the company offers to meet the needs of the customer. Most systems use line power rather than solar power to reduce O&M costs and increased reliability.[159]

For six types of intersection collision warning scenarios, the cost of the design and equipment ranges from $47,230 to $73,320 per intersection. Design cost totaled $19,980 and included data collection, analysis and system design, human factors testing, and software design. The remaining costs were for the equipment (e.g., dynamic message signs (DMS), loop detectors, controllers) and communication devices at one-fourth mile spacing.[160]

FOR SIX TYPES OF INTERSECTION COLLISION WARNING SCENARIOS, THE COST OF THE DESIGN AND EQUIPMENT RANGES FROM $47,230 TO $73,320 PER INTERSECTION.,

Deployment

Crash prevention and safety systems are often deployed in non-urban settings to address specific safety issues at spot locations. Figure 5 shows the trends for the number of states adopting crash prevention and safety systems in statewide/rural locations from 2002 to 2006. The four most widely adopted systems are curve speed warning, ramp rollover warning, highway-rail crossing warning systems, and pedestrian safety systems. Next in popularity, and adopted by about half as many states, are downhill speed warning systems, intersection collision warning systems, and animal warning systems. Finally, bicycle warning systems are adopted by about a fourth as many states as the first three systems. The trend for adoption of crash prevention and safety systems in general is rapidly expanding, with the number of states adopting these systems increasing by a factor of two to three over the four-year period.

The 2006 survey of each of the 50 states about deployment of ITS technologies in rural areas and on a statewide basis is the source of deployment statistics presented later in this chapter, unless otherwise noted.

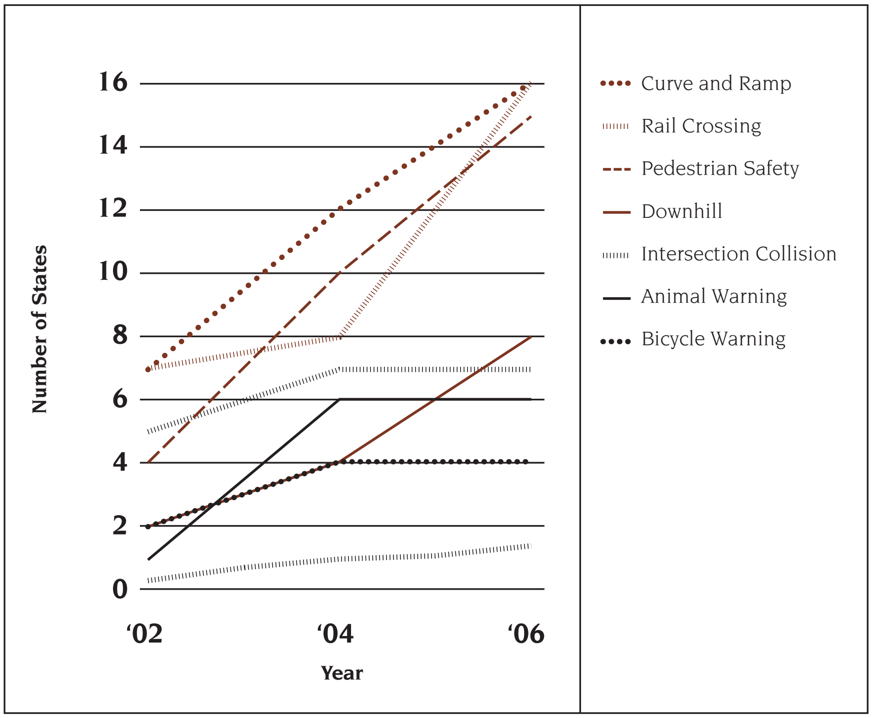

Figure 5 – Trends for Statewide/Rural Deployment of Crash Prevention and Safety Systems, 2002-2006

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Selected Highlights from the ITS Knowledge Resources on Crash Prevention and Safety

Road Geometry Warning Systems

Road geometry warning systems warn drivers, typically those in commercial trucks and other heavy vehicles, of potentially dangerous conditions that may cause rollovers; crashes on ramps, curves, or downgrades; and collisions with roadway infrastructure, such as overpasses.

Road Geometry Warning Systems
Deployment
Overheight/overwidth warning systems that warn drivers of vehicles that are too tall or too wide to pass under bridges or through tunnels are used in 23 states. Systems that warn drivers of potentially dangerous speeds in a variety of situations are used by several states: approaching freeway ramps (11 states), curved freeways (11 states) and downhill grades (8 states).

Road Geometry Warning Systems: Ramp Rollover Warning

Ramp rollover warning systems use roadside detectors and electronic warning signs to warn drivers, typically those in commercial trucks and other heavy vehicles, of potentially dangerous approach speeds to freeway ramps.

Road Geometry Warning Systems—Ramp Rollover Warning	
Benefits	
ITS Goals	**Selected Findings**
Safety	***Summary Finding:*** Rollover warning systems dramatically reduce crashes. A truck rollover warning system installed on the Pennsylvania Turnpike was designed to alert truck drivers of a dangerous curve at the Breezewood Interchange. During 21 months of data collection prior to the system deployment, 5 rollover crashes occurred. After deployment, only one crash occurred, which was attributed to a passenger car that went out of control and forced a nearby truck to make a reactive move and roll over.[161] Similar systems were deployed at three sites on the Capital Beltway outside Washington, D.C. where no crashes occurred during three years of post-deployment data collection. Trucks also reduced speeds by an average 8.3 mi/h when warnings were activated.[162]

Road Geometry Warning Systems—Ramp Rollover Warning
Costs
Unit Costs Data Examples (See Appendix A for more detail)
Roadside Detection subsystem: • Inductive Loops on Corridor: $3K-$8K • Remote Traffic Microwave Sensor on Corridor: $9K-$13K per sensor Roadside Information subsystem: • Dynamic Message Sign: $48K-$119K Roadside Telecommunications subsystem: • Conduit Design and Installation—Corridor: $50K-$75K (per mile) • Fiber Optic Cable Installation: $20K-$52K (per mile)
Sample Costs of ITS Deployments
Colorado: A Truck Tip-Over Warning System was deployed on I-70 eastbound just outside Idaho Springs to help prevent rollover crashes. The system consists of two piezo weigh-in-motion devices, vehicle detectors, four fiber optic message signs, computer and associated software, and controller cabinet. The system was deployed at a cost of **$446,687**.[163]

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Road Geometry Warning Systems: Curve Speed Warning

Curve speed warning systems use roadside detectors and electronic warning signs to warn drivers, typically those in commercial trucks and other heavy vehicles, of potentially dangerous speeds on approach to curves on highways.

Road Geometry Warning Systems—Curve Speed Warning	
Benefits	
ITS Goals	**Selected Findings**
Safety	***Summary Finding:*** Evaluation data collected in California and Oregon indicated that 69 to 76 percent of drivers surveyed reduced their speed in response to curve speed warning systems.[164]
Costs	
Unit Costs Data Examples (See Appendix A for more detail)	
Roadside Detection subsystem: • Inductive Loops on Corridor: \$3K-\$8K • Remote Traffic Microwave Sensor on Corridor: \$9K-\$13K per sensor Roadside Information subsystem: • Dynamic Message Sign: \$48K-\$119K Roadside Telecommunications subsystem: • Conduit Design and Installation—Corridor: \$50K-\$75K (per mile) • Fiber Optic Cable Installation: \$20K-\$52K (per mile)	
Sample Costs of ITS Deployments	
California, Colorado, Maryland, and Virginia: As part of an evaluation of automated truck rollover warning systems, PennDOT researched curve speed warning systems in other states. The cost of these systems varied significantly, ranging from **\$50,000 to \$500,000**, as did their configurations: invasive and non-invasive detection, weight-based versus simplified speed class algorithms, and system calibrations for warnings.[165]	

LESSONS LEARNED

Use speed warning signs on dangerous curves to reduce truck speeds.

The Rural ITS Toolbox noted a relatively low-tech approach that was used by Colorado DOT to address high speed trucks in mountainous terrain. Colorado DOT has many highways that run through the mountains and have high truck traffic. The Colorado DOT's experience reveals the following with regard to reducing truck speeds on dangerous curves.

- Consider using simple radar speed detection devices in combination with dynamic message signs (DMS).

To convey to truck drivers their current speed and to warn them of impending curves ahead that can not be safely negotiated at their current speed, use simple radar speed detection devices in combination with DMS. The relatively low-cost system has seen dramatic results. Speed studies conducted before and after the system was installed revealed a reduction in 85th percentile truck speed from 66 to 48 mi/h.[166]

Road Geometry Warning Systems: Downhill Speed Warning

Downhill speed warning systems use roadside detectors and electronic warning signs to warn drivers, typically those in commercial trucks and other heavy vehicles, of potentially dangerous speeds in approach to downhill grades.

Road Geometry Warning Systems—Downhill Speed Warning	
Benefits	
ITS Goals	**Selected Findings**
Safety	A downhill speed warning system installed on I-70 in Colorado decreased truck crashes by 13 percent and reduced the use of run away truck ramps by 24 percent.[167] Speed studies documented a decline in the 85th percentile truck speed from 66 to 48 mi/h.[168]
Customer Satisfaction	A small-scale study of truck drivers who experienced the down-hill speed warning system in Colorado indicated that most drivers thought it was helpful.[169]
Downhill Speed Warning Costs	
Unit Costs Data Examples (See Appendix A for more detail)	
Roadside Detection subsystem: • Inductive Loops on Corridor: $3K-$8K • Remote Traffic Microwave Sensor on Corridor: $9K-$13K per sensor Roadside Information subsystem: • Dynamic Message Sign: $48K-$119K Roadside Telecommunications subsystem: • Conduit Design and Installation—Corridor: $50K-$75K (per mile) • Fiber Optic Cable Installation: $20K-$52K (per mile)	

Road Geometry Warning Systems: Overheight/Overwidth Warning

Overheight/overwidth warning systems use roadside detectors and electronic warning signs to warn drivers of vehicles that are too tall or wide to pass under bridges or through tunnels.

Road Geometry Warning Systems—Overheight/Overwidth Warning	
Benefits	
ITS Goals	**Selected Findings**
Safety	An overheight/overwidth warning system installed at a tunnel in Pennsylvania worked well, with a few notable exceptions. One driver ignored the warnings given by the system. Another assumed that his truck was within the height limit because he did not receive a warning from the system when it was inactive due to mechanical problems.[170] These experiences demonstrate the value of the systems when warnings are heeded, and the importance of maintenance to assure proper performance.
Costs	
Sample Costs of ITS Deployments	
United States: Overheight detection and warning systems typically use infrared light or laser detection systems and warning signs with flashing beacons to warn drivers that their truck exceeds the height of an upcoming bridge or tunnel. Each approach requires a separate system. Installation costs range from **$7,000 to $70,000 per system** (including labor) depending on site conditions, customer needs, design costs, and availability of power. Reported O&M costs are relatively low, ranging from **$1,000 to $2,500 annually**.[171] **Michigan:** An active overheight detection and warning system installed in advance of a sub-standard bridge structure is estimated to cost **$110,000** based on data provided by manufacturers and State DOTs responding to a study conducted for the Michigan DOT. The system consists of an infrared transmitter, receiver, and a warning sign with alternating flashers. The cost estimate is based on the assumption that two installations are deployed one on each side of the bridge.[172]	

Highway-Rail Crossing Systems

Highway-rail crossing systems use detectors, electronic warning signs, and automated enforcement technologies to warn roadway traffic of approaching trains and discourage drivers from violating railroad crossing traffic controls.

Highway-Rail Crossing Systems	
Deployment	
Sixteen (16) states use systems that detect and warn drivers of approaching trains at highway-rail intersections. One state uses an automated enforcement system to detect drivers violating railroad crossing traffic controls.	
Benefits	
ITS Goals	**Selected Findings**
Safety	Installation of a "Second Train Coming" warning system at a light rail transit grade crossing in the suburbs of Baltimore, Maryland, led to a reduction of 26 percent of vehicles crossing the tracks between the two trains.[173] In Los Angeles, California, installation of a similar system yielded a 14 percent reduction in risky pedestrian behavior.[174]
Mobility	The San Antonio, Texas simulations of increased traffic volumes indicated DMS with railroad crossing delay information may decrease system delay by seven percent.[175]
Energy and Environment	Noise levels were measured at a highway-rail intersection before and after installation of an automated horn system in Ames, Iowa. Analysis indicated that areas impacted by noise levels greater than 80 decibels decreased by 97 percent.[176]
Customer Satisfaction	Ninety-three (93) percent of pedestrians surveyed felt safety was improved by the installation of a "Second Train Coming" warning system at a light rail transit grade crossing in Los Angeles, California.[177]

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Highway-Rail Crossing Systems
Costs
Unit Costs Data Examples (See Appendix A for more detail)
Roadside Rail Crossing subsystem: • Rail Crossing Four-Quad Gate, Signals: $90K-$101K • Rail Crossing Train Detector: $12K-$17K Roadside Detection subsystem: • Inductive Loops on Corridor: $3K-$8K • Remote Traffic Microwave Sensor on Corridor: $9K-$13K per sensor Roadside Information subsystem: • Dynamic Message Sign: $48K-$119K Roadside Telecommunications subsystem: • Conduit Design and Installation—Corridor: $50K-$75K (per mile) • Fiber Optic Cable Installation: $20K-$52K (per mile)

Intersection Collision Warning

Intersection collision warning systems use sensors to monitor traffic approaching dangerous intersections and warn vehicles of approaching cross traffic, via external signage or in-vehicle warnings.

Intersection Collision Warning	
Deployment	
Seven states use intersection collision warning systems that use sensors to monitor traffic approaching intersections and warn drivers of approaching cross traffic.	
Benefits	
ITS Goals	**Selected Findings**
Safety	Field testing of a warning system at a two-way, stop-controlled intersection in rural Virginia reduced vehicle speeds by 2.4 mi/h and increased the average projected time to collision from 2.5 to 3.5 seconds.[178] Intersection collision avoidance systems deployed at intersections with high crash frequencies or high rates of severe injury are projected to recoup initial costs within one year through a reduction in crashes.[179]

Intersection Collision Warning
Costs
Unit Costs Data Examples (See Appendix A for more detail)
Roadside Detection subsystem: • Inductive Loops on Corridor: $3K-$8K • Remote Traffic Microwave Sensor on Corridor: $9K-$13K per sensor Roadside Control subsystem: • Signal Controller and Cabinet: $8K-$14K Roadside Information subsystem: • Dynamic Message Sign: $48K Roadside Telecommunications subsystem: • Conduit Design and Installation—Corridor: $50K-$75K (per mile) • Fiber Optic Cable Installation: $20K-$52K (per mile)
Sample Costs of ITS Deployments
Virginia, California, and Minnesota: Infrastructure-only intersection collision avoidance systems deployed at high crash intersections in three states ranged in costs from **$47,995 to $73,230 per intersection**. Costs included design and capital costs.[180]

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Pedestrian Safety

Pedestrian safety systems can help protect pedestrians by automatically activating in-pavement lighting to alert drivers as pedestrians enter crosswalks. Other systems include countdown pedestrian traffic signals and pedestrian detectors that extend the WALK phase for pedestrians needing more time to cross a street.

Pedestrian Safety	
Deployment	
Fifteen (15) states use pedestrian safety systems to protect pedestrians by alerting drivers when pedestrians enter crosswalks.	
Benefits	
ITS Goals	**Selected Findings**
Safety	Automated pedestrian detection at signalized intersections tested in 3 U.S. cities reduced vehicle-pedestrian conflicts by 89 percent in the first half of the crossing and by 43 percent in the second.[181] The systems—tested in Los Angeles, California; Rochester, New York; and Phoenix, Arizona—also reduced the number of pedestrians who began crossing during the steady DON'T WALK signal by 81 percent.[182]
Costs	
Unit Costs Data Examples (See Appendix A for more detail)	
Roadside Detection subsystem: • Pedestrian Detection—Microwave: $0.6K • Pedestrian Detection—Infrared: $0.3K-$0.5K Roadside Information subsystem: • Light-Emitting Diode (LED) Countdown Signal: $0.306K-$0.424K • Pedestrian Crossing Illumination System: $26.8K-$41K Roadside Telecommunications subsystem: • Conduit Design and Installation—Corridor: $50K-$75K (per mile) • Fiber Optic Cable Installation: $20K-$52K (per mile)	

LESSONS LEARNED

Thoroughly test, evaluate, and maintain animal warning systems.

Animal warning systems are relatively new, having yet to be deployed on a large scale nationally. It is likely that common problems will surface, which will need to be remedied. In order to mitigate emerging complications, deploying agencies need to develop a system that provides assurance that animal warning systems will be continually evaluated and maintained to the highest possible standard.

- Extensively test system components and specifications in environments similar to those experienced at potential animal warning system sites.

The specifications of all components of the system should be checked and compared to specific requirements in the contract including Federal and State regulations, the Federal Communications Commission regulations for radio signals, maximum heights, and break-away construction for objects placed in the clear zone. All system components should be designed to withstand their own weight, strong winds, heavy precipitation (including snow load and ice build-up), and in some cases, high humidity. The site-specific design for the location of posts and sensors should pay special attention to curves, slopes, rises, low areas, and vegetation in the right-of-way to avoid "blind spots" where the sensors cannot detect the target species. Final selection of equipment placement sites should be verified by an on-site electronic survey using a portable beam-break system.[185]

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Bicycle Warning

Bicycle warning systems can use detectors and electronic warning signs to identify bicycle traffic and notify drivers when a cyclist is in an upcoming segment of roadway to improve safety on narrow bridges and tunnels.

Bicycle Warning
Deployment
Four states use bicycle warning systems that warn drivers of the presence of bicycles on narrow bridges and tunnels.

Animal Warning

Animal warning systems typically use infrared or other detection technologies to identify large animals approaching the roadway and alert drivers by activating flashers on warning signs located upstream of high frequency crossing areas. These systems may also activate in-vehicle warning devices.

Animal Warning	
Deployment	
Six states have deployed animal warning systems that warn drivers of large animals approaching the roadway.	
Benefits	
ITS Goals	**Selected Findings**
Safety	In Switzerland, an animal warning system installed at 7 sites decreased collisions with large animals by 81 percent.[183]
Costs	
Sample Costs of ITS Deployments	
United States and Europe: The cost of animal detection systems vary depending on road length and the cost of research and development. The costs for planning, purchase, installation, and operation and maintenance on a one-mile section of roadway have been estimated at **$31,300 per year** with a 10-year lifespan.[184]	

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