

Intelligent Transportation Systems at Highway-Rail Intersections

A Cross-Cutting Study



Improving Safety and Mobility at Highway-Rail Grade Crossings

December 2001

Executive Summary

In 1997, the ITS Joint Program Office (JPO) at the Federal Highway Administration commissioned a study to identify projects being conducted in the U.S. that used Intelligent Transportation Systems (ITS) at highway-rail grade crossings, including not only those projects that were Federally-sponsored, but state and locally-sponsored ones, as well. The study identified seven projects that tested five functions: in-vehicle warning, second train warning, use of crossing blockage information for traveler information and traffic management, four quadrant gates with automatic train stop, and a comprehensive set of technologies called the Intelligent Grade Crossing. The following year, the JPO commissioned a cross-cutting study to examine the commonalities and differences among the seven projects. This report documents the findings of that cross-cutting study:

- Several railroads were reluctant to fully participate in the projects due to liability, safety and operational concerns. Although there were exceptions, passenger railroads – and, in particular, light rail transit – tended to be more involved in these projects than freight railroads.
- In all but one of the seven projects examined in this study, the largest share of funding came from the Federal level, through either direct Federal grants or Congressional designations. In the one project that was the exception to this rule, the largest share of funding came from a private sector technology vendor who made in-kind contributions, using the opportunity of the test to refine its prototype system. Furthermore, in this project, the Federal government was by far the largest public sector contributor of funding.
- While the initial deployment of all the systems was funded primarily from Federal sources, those agencies that have continued to operate or even develop enhancements to their systems following conclusion of the tests have done so with local funds.
- In fact, agencies involved in the majority of projects continued to operate their ITS systems after the completion of the evaluation phase. Only in projects involving in-vehicle navigation systems did agencies remove the equipment following completion of testing. In contrast, tests of second train coming signs, use of crossing blockage information, four quadrant gate systems with automatic train stop and the Intelligent Grade Crossing continued, and in some cases expanded, operation of these systems.

- Evaluation results from these projects indicate that ITS technologies have a positive impact in increasing safety and mobility at highway-rail grade crossings:

In-vehicle warning: Due to the small scope of deployment (30 drivers) in the Minnesota test of in-vehicle warning systems, it is difficult to draw larger conclusions about driver behavior from these results. However, preliminary findings from a larger scale evaluation (300 drivers) of a similar system in Illinois show that, although test participants recommended several human factors improvements, the system was helpful in focusing drivers' attention to the presence of an on-coming train.

Use of crossing blockage information for traveler information and traffic management: Simulation of the Advanced Warning to Avoid Railroad Delay (AWARD) system installed in San Antonio, Texas estimated that incorporation of information on crossing blockages into traveler information and traffic management resulted in modest (16%-19%) decreases in travel time delay for affected motorists: a 19% reduction for drivers who followed the system's advice to reroute and a 16% reduction area-wide.

Second train warning: Tests of second train coming signs in Maryland and California showed a notable reduction in risky behavior of drivers (36%) and a modest reduction in risky behavior of pedestrians (14%).

Four quadrant gate with automatic train stop: Preliminary findings from analysis of videotaped observations of driver behavior revealed that risky behavior of drivers decreased significantly following installation of a four quadrant gate with automated train stop system in Connecticut.

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INTRODUCTION

Intelligent Transportation Systems are "electronics, communications or information processing, used singly or in combination, to improve the efficiency or safety of a surface transportation system" according to the Transportation Equity Act for the 21st Century (TEA-21), the surface transportation authorizing legislation passed in 1998. The history of ITS goes back to the previous authorizing legislation, the Intermodal Surface Transportation Efficiency Act (ISTEA), passed in 1991. That law specifically cited the potential of ITS – which at the time was called Intelligent Vehicle Highway Systems (IVHS) – to achieve significant transportation safety and efficiency benefits.

Unfortunately, through the first half of the 1990's, ITS research and testing proceeded almost entirely without consideration how these technologies could improve the efficiency of rail transportation or improve safety at points where rails and highways meet. Then, in October of 1995, a commuter train struck a school bus at a crossing in Fox River Grove, Illinois. Seven high school students died in the crash.

Following the incident, the public sector at the Federal, state and local level, in partnership with the railroad industry, turned greater attention to exploring how ITS technologies could be used to improve safety and mobility at highway-rail grade crossings. The ITS Joint Program Office included Highway-Rail Intersections (HRI's) as a major component of its Metropolitan ITS Infrastructure Program, and the Federal Railroad Administration initiated an effort, completed in 1997, to add an ITS User Service for Highway-Rail Intersections to the National ITS Architecture.¹

Prior to the Fox River Grove crash, several projects were already underway to test these new ITS technologies and their ability to reduce the likelihood of a grade crossing crash. One of the earliest efforts – the Vehicle Proximity Alert Systems (VPAS) project – tested several in-vehicle warning systems at the Transportation Technology Center, Inc. (TTCI) rail test facility in Pueblo, Colorado.² These systems were similar to the in-vehicle warning systems tested in Illinois and Minnesota that are profiled in the report.

In addition, following the Fox River Grove crash, several additional tests were initiated nationwide. Some projects were sponsored directly by Federal agencies. Others were grass-roots initiatives included as part of corridor or statewide Congressionally designated programs that the local participants chose to pursue without Federal guidance.

¹ The FRA has established a website for ITS and the Highway-Rail Intersection. The site provides background on the use of ITS at HRI's, such as the development of the ITS User Service of the National ITS Architecture, as well as development of ITS standards, operational tests and a strategic plan. The website address is <http://www.fra.dot.gov/o/dev/its/hri/a.htm>.

² The project final report *Vehicle Proximity Alert System for Highway-Railroad Grade Crossing Prototype Research* is available online at http://www.itsdocs.fhwa.dot.gov/jpodocs/repts_te/13485.pdf.

In 1997, the ITS Joint Program Office at the Federal Highway Administration commissioned a study to identify these various projects, including not only those projects that were Federally-sponsored but state and locally-sponsored ones as well. That study identified seven projects that tested a five different functions: in-vehicle warning, second train warning, use of crossing blockage information for traveler information and traffic management, four quadrant gates with automatic train stop, and a comprehensive set of technologies called the Intelligent Grade Crossing. The following year, the JPO commissioned a cross-cutting study to examine the commonalities and differences among the seven projects. This report documents the findings of that cross-cutting study.

Data collection included review of existing literature, interviews of project contacts and site visits. In addition, representatives of the projects participated in an *HRI-ITS Evaluation Workshop* held in Cambridge, Massachusetts May 6-7, 1999, in which speakers were invited to describe their implementation plans and evaluation results to date.³

For each of the seven projects, this report examines what functions were tested, who were the partners involved (including Federal, state and local governments, technology vendors, and railroads), where the test was conducted and on how many crossings, what was the evaluation methodology used (e.g. driver surveys, simulation modeling or "before" and "after" comparison of risky behavior), and what were the test results (if available). This report lists the overall project costs and sources of funding. The report also lists costs of individual system components or particular phases of the project, if this information was available from local participants.

This report presents references, Internet resources and contacts that the reader can turn to for more information on each project. The report concludes with a discussion of issues and evaluation results common to all the projects, and emerging trends in this field.⁴

³ The workshop proceedings *ITS Technology at Highway-Rail Intersections: Putting It to the Test* are available online at <http://www.itsdocs.fhwa.dot.gov/jpodocs/proceedn/9jf01!.pdf>.

⁴ An annual inventory of HRI-ITS, including the seven projects profiled in this report and as well as three emerging ones, is posted online on the ITS Cooperative Deployment Network (ICDN) website at http://www.nawgits.com/icdn/its_hri.html.

Project Profiles

California: Los Angeles Light Rail Transit Second Train Coming



Project Description

The Los Angeles County Metropolitan Transportation Authority (LACMTA) tested a second train warning system: a fiber-optic message sign that warns pedestrians of situations where two or more trains – two light rail transit (LRT) trains or a combination of LRT trains and Union Pacific Railroad's freight trains – approach the crossing.

The same track circuitry used to detect trains to activate the crossing's gates, lights and bells identifies when a second train is approaching the crossing shortly after an initial train. A signal is then sent to activate the second train coming sign, which stays illuminated until the second train has passed through the crossing, the gates are raised, and the lights and bells deactivate.

The system was tested at one crossing in Los Angeles, California on the Los Angeles County Metropolitan Transportation Authority's light rail transit line, at the intersection of the Blue Line and Vernon Avenue. The sign was made operational on June 9, 2000 but failed the next day because of a defective flasher unit and was out of service until July 29. The collection of post-installation data was further delayed by eight months because of a labor strike and malfunctions of the video camera used for data collection. The last phase of data collection was conducted from May 20 through June 18, 2001. PB Farradyne is serving as the independent evaluator during the test.

Videotaped observation around the crossing revealed that risky behavior of pedestrians – entering the track area six seconds or less before the train entered the crossing –

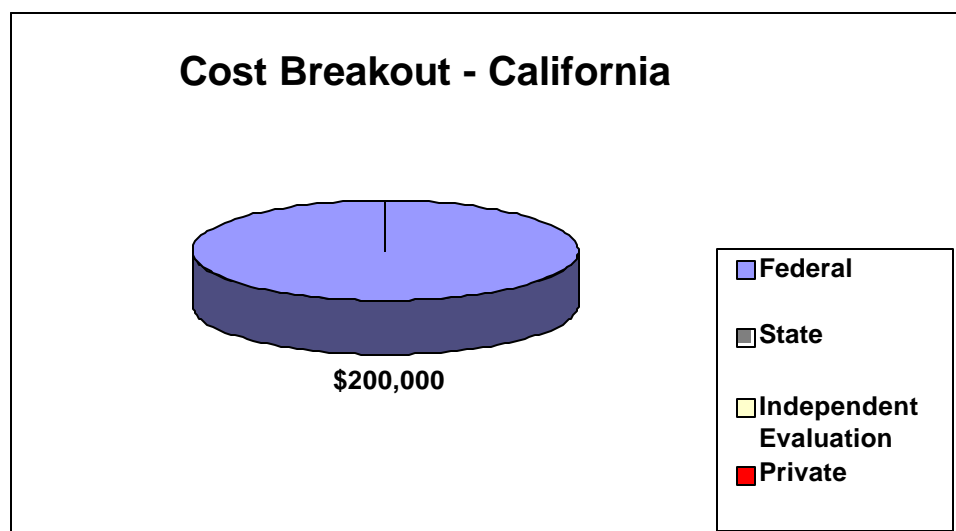
decreased by 14% after installation of the system. The final report is scheduled to be complete by Fall 2001.

In addition, the LACMTA conducted on-site surveys of over 500 pedestrians to assess the effectiveness of the second train warning sign. The majority of the respondents felt that the sign improved safety at the Vernon Avenue crossing "to a great extent" (63%) or "to some extent" (30%).

Using its own funds, the LACMTA plans to continue to operate the second train coming sign following completion of the test.

Funding and Costs

This \$200,000 project was funded entirely by a grant from the Transit Cooperative Research Project (TCRP) program of the Transportation Research Board. The grant was administered by the Federal Transit Administration's Office of Technology.



The costs of system components and individual project phases are shown in the table below.

Item	Cost
Sign and video equipment	\$25,000
Installation and construction	\$70,000
Design, data collection and evaluation support	\$60,000
Sign selection, effectiveness surveys and public education	\$45,000
Total	\$200,000

References

- *Los Angeles Metro Blue Line Second Train Warning Sign Demonstration Project: Quarterly Progress Report* (Los Angeles, CA: Los Angeles County Metropolitan Transportation Authority, July 12, 2001).
- Khawani, V.J. "Los Angeles County Metropolitan Transportation Authority – Metro Blue Line Second Train Warning Sign Demonstration Project" *Presentation to the 1999 Highway-Rail Grade Crossing Safety Conference* (College Station, TX: Texas Department of Transportation, October 17-19, 1999).

Internet Resources

The Los Angeles County Metropolitan Transit Authority has created a web page for the project at http://www.mta.net/other_info/safety/programs/trainact.htm.

Contacts

V.J. Khawani
Los Angeles County Metropolitan Transportation Authority
One Gateway Plaza, 17th Floor
Los Angeles, CA 90012
Tel: (213) 922-7275
Fax: (213) 922-3879
E-mail: KhawaniV@mta.net

Jim Curry
PB Farradyne
505 S. Main Street, Suite 900
Orange, CA 92868
Tel: (714) 973-4880
Fax: (714) 973-0358
E-mail: CurryJ@pbworld.com

Connecticut: Four-Quadrant Gate with Automatic Train Stop



Project Description

The Connecticut Department of Transportation, in conjunction with Amtrak, tested a four-quadrant gate system with an obstruction detection function that interfaces with Amtrak's in-cab signaling system. Motivation for this project came about from the need to enhance traffic control devices and train signals at a crossing along the East Coast high-speed rail corridor designated for the Amtrak *Acela* train. The particular geometry of this crossing made grade separation neither a feasible nor cost-effective option.

A system of four gates was used rather than the usual two, to prevent waiting vehicles from starting to cross the tracks and, thus, running the gate. Six inductive loop sensors, embedded within the crossing, were used to detect if a vehicle or other obstacle was blocking the crossing. The interface with the Amtrak in-cab signaling system provided the locomotive engineer with a notice to stop the train safely before it reached the crossing. If the engineer failed to reduce the train's speed, the in-cab signaling system would stop the train automatically.

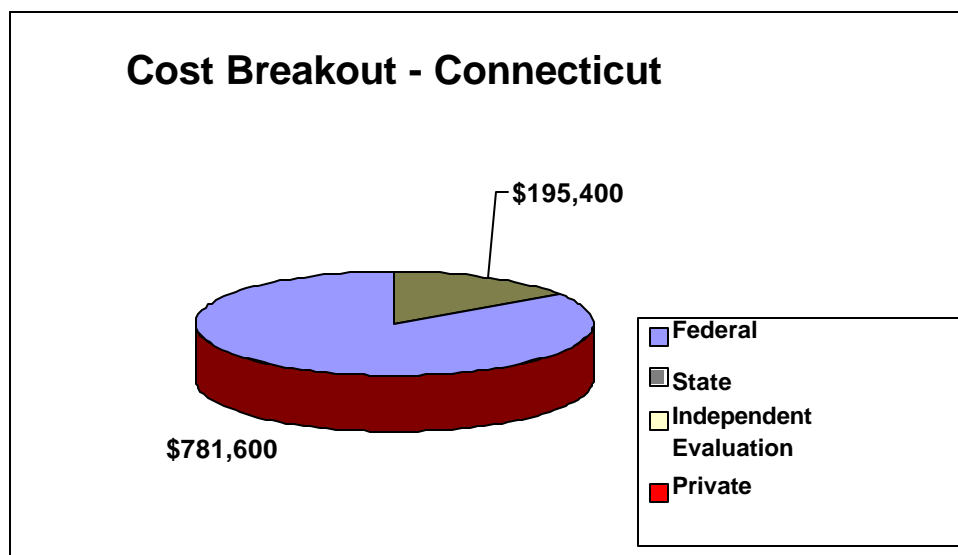
The system was installed at the intersection of School Street and the Amtrak rail line in Groton, Connecticut. Testing took place from January 1999 through the end of September 2000. The Volpe National Transportation Systems Center is serving as the independent evaluator for the test.

A final evaluation report is expected to be available January 2002. Preliminary findings from analysis of videotaped observations of driver behavior revealed that risky behavior of drivers decreased significantly following the upgrade at the crossing from conventional two-quadrant gates to four-quadrant gates with automatic train stop.

The *Acela* went into revenue service in December 2000. Using its own funds, Amtrak continues to operate the system following completion of the test and has expanded the system to four additional crossings along the *Acela* high-speed rail line in Connecticut.

Funding and Costs

The almost \$1 million project was funded primarily by a grant from the Federal Railroad Administration.



The costs of system components and individual project phases are shown in the table below.

Item	Cost
Materials	\$242,000
Labor	\$710,000
Grant administration	\$25,000
Total	\$977,000

References

- *National High Speed Ground Transportation Technology Demonstration Program School Street West Mystic (Groton) Connecticut* (Newington, CT: Connecticut Department of Transportation).
- Hellman, Adrian. "School Street Four-Quadrant Gate In-Cab/At Grade Crossing: Preliminary Evaluation Results" *Presentation to the California Public Utilities Commission Annual State/Railroad Meeting* (San Diego, CA: California Public Utilities Commission, August 13-17, 2001).

Internet Resources

None

Contacts

Steve Szegedy
Connecticut Department of Transportation
P.O. Box 317546
Newington, CT 06131
Tel: (860) 594-2897
Fax: (860) 594-2913
E-mail: SSzegedy@aol.com

Adrian Hellman
Volpe National Transportation Systems Center
55 Broadway, Kendall Square
Cambridge, MA 02142
Tel: (617) 494-2171
Fax: (617) 494-2318
E-mail: Hellman@volpe.dot.gov

Illinois: Gary-Chicago-Milwaukee Corridor In-Vehicle Warning



Project Description

The Illinois Department of Transportation contracted with a team lead by Raytheon Company to design and install an in-vehicle warning system and test that system in an operational railroad crossing environment.

The contract team included Cobra Electronics, Calspan SRL and the Metro Transportation Group as subcontractors. The same track circuitry used to detect a train to activate the crossing's gates, lights and bells identifies when a transmitter, located trackside, should send a signal to the in-vehicle receiver. A receiver activated when an equipped vehicle came within a certain distance of a transmitter and a train had been detected at or approaching that crossing. The in-vehicle receiver was capable of operating in three modes: audible only, visual only and combination audible/visual.

The advisory in-vehicle warning devices were installed in approximately 300 vehicles, including school buses, emergency vehicles (police, fire, ambulance), and commercial vehicles that regularly traverse the study area. The study area included five railroad grade crossings on the Metra-Milwaukee North Line that traverses the northern Chicago suburbs. The University of Illinois at Urbana-Champaign is serving as the independent evaluator for the test.

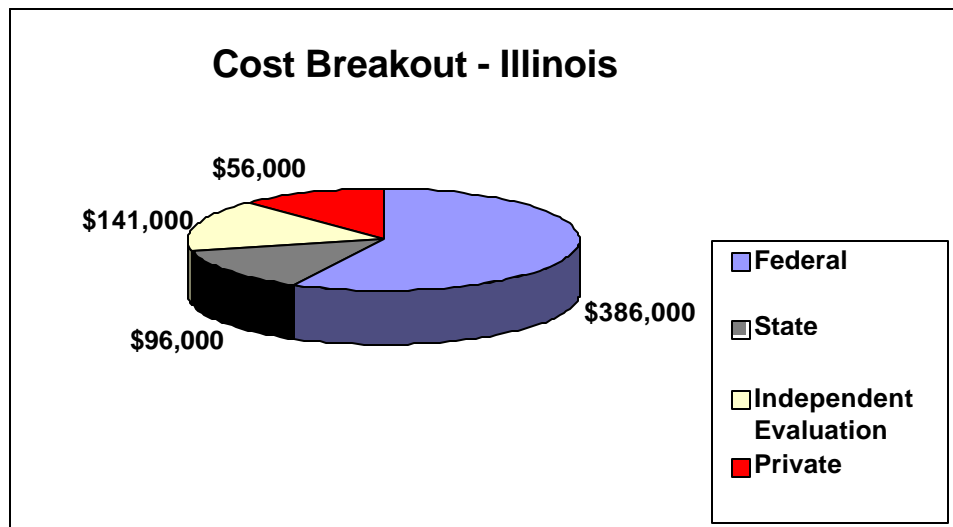
The deployment phase of the pilot study ran from March through December 2000. The final evaluation report is expected to be available in late 2001. Preliminary findings show that, although test participants recommended several human factors

improvements, the system was helpful in focusing drivers' attention to the presence of an on-coming train.

All project equipment, including in-vehicle warning devices and track-side components, was removed following completion of the test.

Funding and Costs

This almost \$700,000 project was funded primarily as part of the Congressionally designated Gary-Chicago-Milwaukee ITS Corridor program that has been on-going since the early 1990's.



Cost data were not collected by project participants.

References

- *Pilot Study of Advisory On-Board Vehicle Warning Systems at Railroad Grade Crossings: Executive Summary* (Schaumburg, IL: Illinois Department of Transportation, August 20, 1997).
- *Pilot Study of Advisory On-Board Vehicle Warning Systems at Railroad Grade Crossings* (Schaumburg, IL: Illinois Department of Transportation, September 27, 1999).
- Benekohal, Rahim. "Pilot Study of Advisory On-Board Vehicle Warning Systems at Railroad Grade Crossings" *Presentation to the ITS Highway-Rail Intersection Evaluation Workshop* (Cambridge, MA: Volpe National Transportation Systems Center, May 6-7, 1999).

Internet Resources

None

Contacts

Chuck Sikaras
Illinois Department of Transportation
120 W. Center Court
Schaumburg, IL 60195
Tel: (847) 705-4800
Fax: (847) 705-4803
E-mail: sikarasc@nt.dot.state.il.us

Rahim Benekohal
University of Illinois
205 N. Mathews Ave., 1201 Newmark
Urbana, IL 61801
Tel: (217) 244-6288
Fax: (217) 333-1924
E-mail: RBenekoh@uiuc.edu

Maryland: Baltimore Light Rail Transit Second Train Coming



Project Description

The Maryland Mass Transit Administration (MTA) tested a second train warning system: a variable message sign that warns drivers and pedestrians in situations where a second train is approaching the crossing soon after an initial train has cleared the crossing.

The same track circuitry used to detect trains to activate the crossing's gates, lights and bells identifies when a second train is approaching the crossing shortly after an initial train. A signal is then sent to activate the second train coming sign, which stays illuminated until the second train has passed through the crossing, the gates are raised, and the lights and bells deactivate.

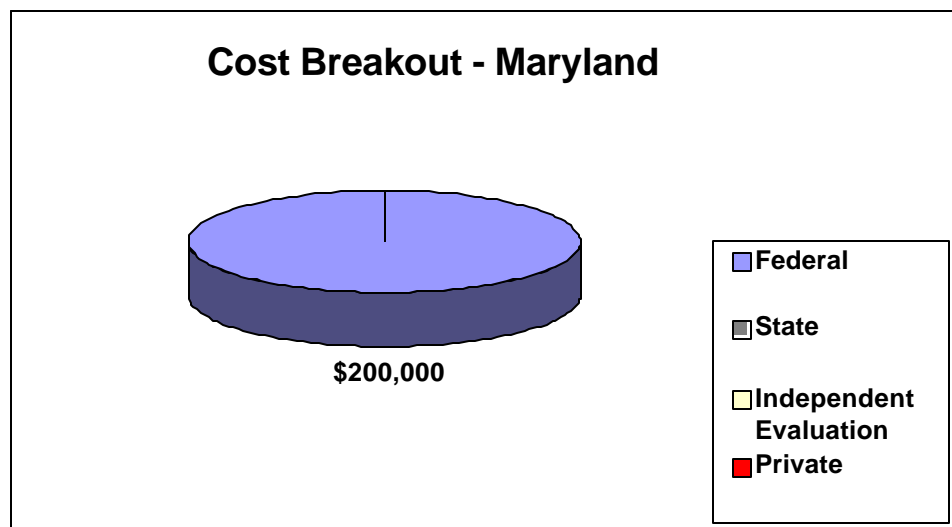
The system was tested at one crossing in Timonium, Maryland on the Maryland Mass Transit Administration's light rail transit line. Sabra, Wang & Associates served as the independent evaluator during the test.

Testing took place in Fall 1998 and Winter 1999. A final report was submitted to the Transportation Research Board in February 2001. Videotaped observation around the crossing revealed that risky behavior of drivers decreased by 36% after installation of the system.

Using its own funds, the MTA continues to operate the second train coming sign following completion of the test.

Funding and Costs

This \$200,000 project was funded entirely by a grant from the Transit Cooperative Research Project program of the Transportation Research Board. The grant was administered by the Federal Transit Administration's Office of Technology.



The costs of system components are shown in the table below.

Item	Cost
Four closed-circuit TV (CCTV) cameras, recording equipment and remote playback station (including installation)	\$36,670
Conduits and cables needed for CCTV system (including installation)	\$28,760
Active matrix high intensity signs, strobe lights, modems mounting hardware and software to control sign	\$30,000
Portable sign programmer	\$2,550
Spare parts kit for signs	\$2,240
Printer and CD-ROM for playback station	\$560
Extra data pack for playback station	\$360
Cantilever mounting fixtures	\$1,200
Four pedestrian crosswalk signals with bases, masts and side-mounting hardware	\$4,000
Scale model of grade crossing for training and presentation purposes	\$1,500
"Second train coming" signs and pedestrian signals (including installation)	\$15,480
Public opinion survey of 10,000 residents	\$3,790
Consultant/engineering services	\$23,000
Transit authority employees' time charged to project	\$23,000

Other expenses	\$26,890
Total	\$200,000

References

- *Final Report for Second Train Coming Warning Sign Demonstration Project* (Baltimore, MD: Maryland Mass Transit Administration, February 2001).
- Hartsock, Vernon. "Second Train Coming Warning Signal Demonstration" *Proceedings of the 1999 Highway-Rail Grade Crossing Safety Conference* (College Station, TX: Texas Transportation Institute, October 17-19, 1999).

Internet Resources

The Maryland Mass Transit Administration has created a web page for the project at <http://www.bcpl.net/~vhartsoc/stcweb.htm>.

Contacts

Vernon Hartsock
Maryland Mass Transit Administration
6 St. Paul Street
Baltimore, MD 21202
Tel: (410) 767-3318
Fax: (410) 333-7617
E-mail: VHartsoc@bcpl.net

Ziad Sabra
Sabra, Wang & Associates, Inc.
1506 Joh Avenue, Suite 180
Baltimore, MD 21227
Tel: (410) 737-6564
Fax: (410) 737-1774
E-mail: ZSabra@sabra-wang.com

Minnesota: In-Vehicle Warning



Project Description

In 1995, the Minnesota Department of Transportation partnered with 3M Corporation and Dynamic Vehicle Safety Systems (DVSS) to develop an in-vehicle warning system, and test that system in an operational railroad crossing environment. In addition, the partners tested a passive train detection system developed by DVSS.

The system used 3M's wireless vehicle and roadside communication antennas that could be built into the familiar crossbuck, "RXR" sign and front vehicle license plate. The trackside unit picked up a signal from the railroad's train detection electronics and transmitted that signal to 3M's antenna-signs. The in-vehicle display, provided by DVSS, alerted drivers using both visual and audible signals.

The passive train detection system listened for an internal radio frequency communication, called Head-Of-Train (HOT), used by most railroads to coordinate braking between the front and rear of the train. The HOT passive train detectors were installed directly onto the school buses, so that no special equipment was needed at the crossing infrastructure. SRF Consulting Group, Inc. served as the independent evaluator during the tests.

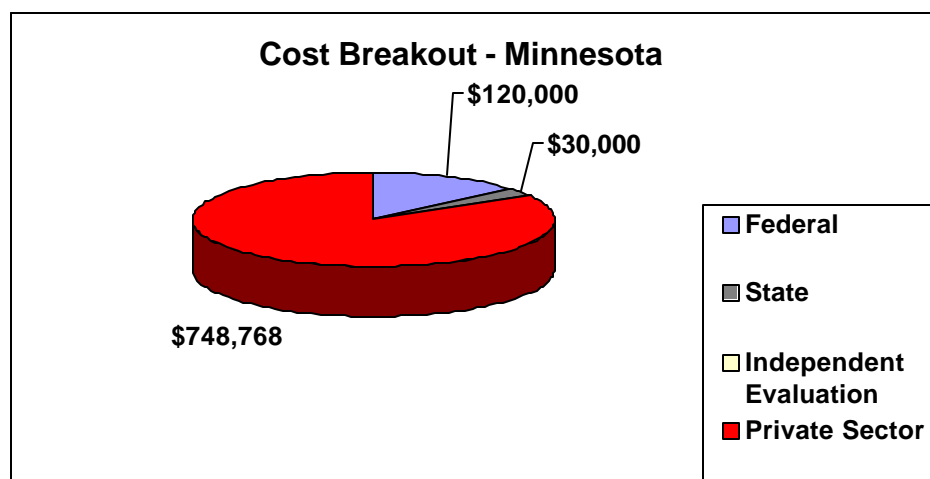
Testing took place on about 30 school buses at five revenue service crossings, operated by Twin Cities & Western Railroad, in Glencoe, Minnesota – a rural community 30 miles west of the Minneapolis-St. Paul metropolitan area. Testing of the in-vehicle warning system took place from December 1997 to May 1998. Testing of the passive train detection system took place in June 1998.

The project was completed in September 1998 with the publication of a final report. Because the scope of deployment was so small, the impact of the system on network performance measures, such as the number of crashes, could not be measured directly. Instead, school bus drivers were surveyed to determine their perception of the system. Eighty percent (80%) of the drivers surveyed thought that the system provided valuable warning information, although it did not affect their driving behavior. Only 15% of drivers surveyed reported that the system affected their driving behavior. One survey respondent said that the system helped her avoid a crash.

All project equipment, including in-vehicle warning devices and track-side components, was removed following completion of the test.

Funding and Costs

The largest share of funding for this almost \$1 million project came from in-kind donations by the private sector. Of the public funds contributed to the project, the largest share came from the Minnesota Guidestar program – Minnesota's Congressionally designated statewide ITS program that has been on-going since the early 1990's.



Cost data were not collected by project participants.

References

- *An In-vehicle Signing System for School Buses at Railroad-Highway Grade Crossings: Evaluation Report* (St. Paul, MN: Minnesota Department of Transportation, August 1998), EDL# 5516.
http://www.itsdocs.fhwa.dot.gov/jpodocs/repts_te/49801!.pdf
- Minge, Erik. "In-Vehicle Signing: An ITS Operational Test at Highway-Rail Grade Crossings" *Presentation to the ITS Highway-Rail Intersection Evaluation*

Workshop (Cambridge, MA: Volpe National Transportation Systems Center, May 6-7, 1999).

Internet Resources

The Minnesota Department of Transportation has created a web page for the project at <http://www.dot.state.mn.us/guidestar/railcrossings.html>.

Contact

Erik Minge
SRF Consulting Group, Inc.
One Carlson Parkway North, Suite 150
Minneapolis, MN 55447
Tel: (763) 475-0010
Fax: (763) 475-2429
E-mail: EMinge@srfconsulting.com

New York: Long Island Railroad Intelligent Grade Crossing



Project Description

New York State Department of Transportation partnered with Alstom Signaling, formerly known as General Railway Signal Corporation, to develop an Intelligent Grade Crossing (IGC) that used ITS technologies to perform a number of functions to improve railroad crossing safety and minimize inconvenience to the driver:

- **Constant Warning Time:** The Intelligent Grade Crossing provided a constant 30-second warning time to drivers, regardless of the train's speed or type, by activating both the crossing's active warning signals as well as nearby variable message signs (see below).
- **Transient Gate Control:** When two trains traversed the crossing within a short period of time of each other, the system left gates down instead of raising them only to lower them again quickly.
- **Emergency Vehicle Priority:** If an equipped emergency vehicle needed to cross the tracks, it could send a message via wireless communications to the Intelligent Grade Crossing. The IGC then caused the train to safely brake prior to the crossing, if the train's speed and distance allowed. Otherwise, the request was denied until the train had passed.
- **Minimization of Gate Down Times:** The Intelligent Grade Crossing minimized gate down times, making operation of the signal system more reliable to drivers.
- **Variable Message Signs:** The Intelligent Grade Crossing allowed nearby variable message signs to display messages that informed drivers of current

conditions at the crossing. Messages displayed included "Train Approaching", "Crossing Delay", "Exit Lane Blocked" and "Train in Station".

- **Stalled Automobile Detection:** A combination of conventional loop detectors and high-tech video-based sensors detected if a vehicle was stalled on the tracks or if a vehicle was unable to exit the crossing area. If the crossing was blocked for any reason, a signal was sent to the locomotive engineer in time to stop the train before it reached the crossing or slow the train down as much as possible. A back-up system could also stop or slow the train – equipped with Positive Train Control (PTC) technology – automatically, if necessary.
- **Queued Vehicle Detection:** The system detected if a long queue of vehicles was waiting at a traffic signal thus backing up traffic onto the crossing. The system then could use the variable message signs to encourage drivers not to traverse the crossing. In addition, if the system was tied into the traffic signal that was causing the queue, it could turn the signal green for that approach in order to eliminate the queue and clear the crossing.

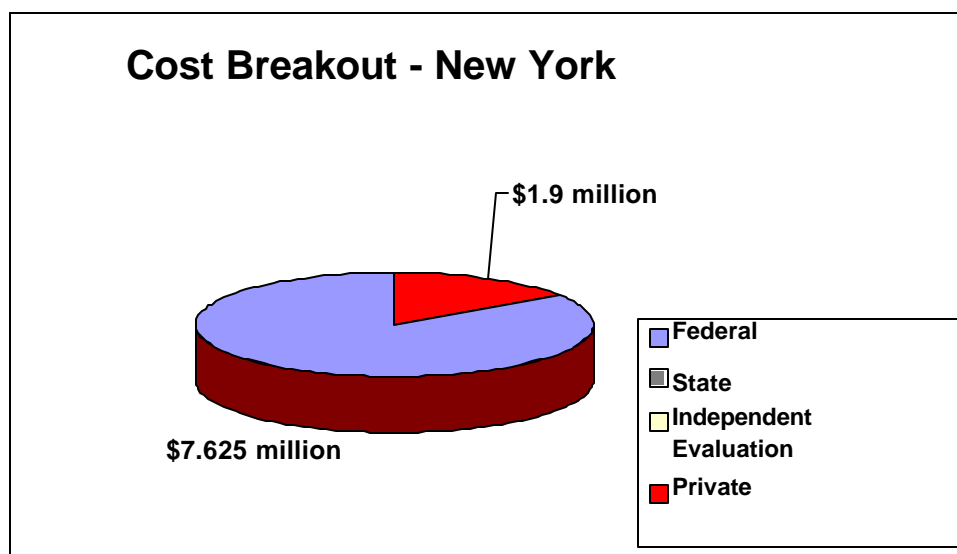
The stalled automobile detection and variable message signs functions were showcased in an operational environment at one crossing in New Hyde Park, New York during a demonstration in June 2001.

The Volpe National Transportation Systems Center is conducting a cost-benefit analysis and effectiveness study of the system. The report, which will document the findings from both studies, is expected to be complete by Fall 2002.

The IGC has been taken out of operation in order to pursue development of an enhanced system, which is being funded by the New York State Department of Transportation, independent of Federal support. The enhanced IGC system will incorporate train location information derived from the satellite-based global positioning systems (GPS).

Funding and Costs

The largest share of funding for this almost \$10 million project came from Congressional designations included in three consecutive Transportation Appropriations bills in FY95, FY96 and FY97. The private sector partner reports that the \$1.9 million in in-kind contributions is only a lower limit of what was actually contributed and the company may have exceeded that amount.



Cost data were not collected by project participants.

References

- *Long Island Rail Road ITS-Based Intelligent Highway-Railroad Grade Crossing System Project* (Albany, NY: New York State Department of Transportation, February, 1999).

Internet Resources

None

Contacts

Seth Edelman
New York State Department of Transportation
1220 Washington Ave.
State Campus Building 7A, Room 304
Albany, NY 12232
Tel: (518) 457-4650
Fax: (518) 457-3183
E-mail: SEdelman@gw.dot.state.ny.us

Steve Zwart
Alstom Signaling, Inc.
150 Sawgrass Drive
Rochester, NY 14620
Tel: (716) 783-2218
Fax: (716) 783-2080
E-mail: Steve.Zwart@transport.alstom.com

Douglass Lee
Volpe National Transportation Systems Center
55 Broadway – Kendall Square
Cambridge, MA 02142
Tel: (617) 494-2762
Fax: (617) 494-3260
E-mail: LeeD@volpe.dot.gov

Texas: San Antonio AWARD



Project Description

The Texas Department of Transportation (TxDOT) tested a train detection system for traffic management and traveler information called Advanced Warning to Avoid Railroad Delay or AWARD.

Acoustic sensors and radar speed guns were placed upstream of three locations near the intersection of Woodlawn Avenue and the Union Pacific Railroad line parallel to Interstate 10 in San Antonio. These sensors detected the presence, length and speed of trains approaching the crossings. The duration of blockage was calculated, and the predicted delay was then disseminated in three ways:

- **Variable Message Signs:** Variable message signs (VMS's) upstream to the crossing alerted drivers to take alternate routes or freeway exits to avoid the delay.
- **Traffic Management Center:** The TransGuide traffic management center included the delay information in up-to-the-minute link speeds distributed via the Internet, kiosks and in-vehicle displays.
- **Emergency Vehicles:** Emergency service vehicles such as ambulances used the delay information to plan their routes in real-time.

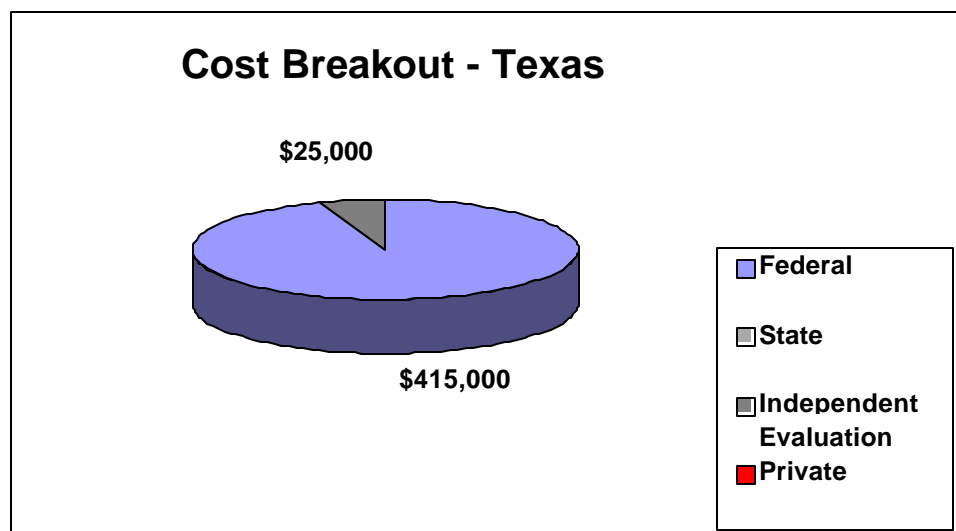
SAIC, funded separately as part of the overall Metropolitan Model Deployment Initiative (see below), evaluated the system's ability to reduce travel time and increase travelers' perceived convenience.

The system became operational Summer 1998. A case study of the AWARD project was published in November 2000. Due to the low frequency of situations where the system could be activated, the impact of the system on network performance measures, such as network-wide travel time delay, could not be measured directly. Instead, the potential impacts of the system at one crossing were estimated using a traffic simulation model. The simulation model estimated that, if slightly less than half (45%) the drivers rerouted based on the VMS message that the crossing was blocked, travel time delay would decrease by 19% for drivers who chose to reroute and by 16% for all drivers in the study population.

Using its own funds, the Texas Department of Transportation continues to operate the AWARD system following completion of the test. As of Summer 2001, TxDOT was in the process of creating an AWARD web page that will display real-time crossing blockage information. In addition, TxDOT is considering expansion of the AWARD system to additional crossings.

Funding and Costs

This almost half-million dollar project was part of the San Antonio Metropolitan Model Deployment Initiative (MMDI), a Federally-funded ITS program in four metropolitan areas to rapidly develop and then showcase integrated ITS systems.



The costs of system components and individual project phases are shown in the table below.

Item	Cost
Twelve (12) sensors	\$120,000
Prototype development	\$230,000
33% share of AWARD/kiosk/in-vehicle navigation master computer	\$5,000
20% share of Southwest Research Institute development labor costs	\$60,000
Miscellaneous private sector expenses	\$25,000
Total	\$440,000

References

- Carter, Mark, Timothy Luttrell and Brandy Hicks. *Advanced Warning for Railroad Delays in San Antonio: Lessons Learned from the Metropolitan Model Deployment Initiative* (Washington, DC: U.S. Department of Transportation, November 2000), EDL# 13485.
http://www.itsdocs.fhwa.dot.gov/jpodocs/repts_te/@9001!.pdf
- Fariello, Brian. "Advance Warning to Avoid Railroad Delays" *Presentation to the California Public Utilities Commission Annual State/Railroad Meeting* (San Diego, CA: California Public Utilities Commission, August 13-17, 2001).

Internet Resources

The Texas Department of Transportation and TransGuide have created a web page for the AWARD project at <http://transguide.dot.state.tx.us/mdi/AWARD.html>.

Contacts

Brian Fariello
Texas Department of Transportation
3500 Northwest Loop 410
San Antonio, TX 78229
Tel: (210) 731-5247
Fax: (210) 731-5310
E-mail: BFariel@dot.state.tx.us

Mark Carter
SAIC
400 Seventh Street, S.W., Room 3416
Washington, DC 20590
Tel: (202) 366-2196
Fax: (202) 366-3302
E-mail: Mark.R.Carter@saic.com

Discussion of Cross-Cutting Issues

Although the seven projects examined in this study tested a wide variety of ITS functions at highway-rail grade crossings, they exhibited similarities in several key areas.

Participation by Railroads

The degree of participation by railroads in these projects varied widely. In some projects, the railroads were reluctant to provide even modest resources. For example, in the Texas AWARD project, the railroad refused to allow the pole-mounted train detection sensors to be installed on the railroad right-of-way, requiring that the sensors to be installed in less-than-optimal locations. In the Long Island Intelligent Grade Crossing Project, the railroad did not allow the only system demonstration to take place during revenue service hours, requiring that the demonstration begin at 1:00am. In contrast, the railroad staff were the main organizers of the Maryland and California second train coming projects. In addition, the Minnesota and Illinois in-vehicle warning projects enjoyed a close working relationship with the railroads involved in their tests. Possible explanations for the railroads' reluctance to participate in these tests include concerns over increased liability, decreased safety and interference with railroad operations.

Although there were exceptions, passenger railroads – and, in particular, light rail transit – tended to be more involved in these projects than freight railroads. This difference may be explained by the fact that transit authorities are public sector entities, a status that offers them a number of legal resources and protections not available to private sector freight railroads.

Funding

In all but one of the seven projects examined in this study, the largest share of funding came from the Federal level, through either direct Federal grants or Congressional designations. In the one project that was the exception to this rule – the Minnesota in-vehicle warning project – the largest share of funding came from a private sector technology vendor who made in-kind contributions, using the opportunity of the test to refine its prototype system. Furthermore, in this project, the Federal government was by far the largest public sector contributor of funding. The dominance of Federal funding also characterizes the three emerging projects profiled below.

However, while the initial deployment of all the systems was funded primarily from Federal sources, those agencies that have continued to operate or even develop enhancements to their systems following conclusion of the tests have done so with local funds.

Continued Operations

All but two of the projects continue to operate their ITS systems after completion of the evaluation phase. The Minnesota and Illinois Departments of Transportation had the in-vehicle warning devices removed from test vehicles following completion of the test. However, transit authorities in California and Maryland continue or plan to continue operation of their second train coming signs. In Texas and Connecticut, the AWARD and automatic stop four quadrant gate systems, respectively, not only continued to operate, but were expanded or are being considered for expansion to additional crossings beyond the scope of the original test. In New York, the Intelligent Grade Crossing has been taken out of operation in order to pursue development of an enhanced system, which is being funded by the New York State Department of Transportation, independent of Federal support.

Evaluation Results

Evaluation results from these projects indicate that ITS technologies have a positive impact in increasing safety and mobility at highway-rail grade crossings.

- **In-vehicle warning:** Due to the small scope of deployment (30 drivers) in the Minnesota test of in-vehicle warning systems, it is difficult to draw larger conclusions about driver behavior from these results. However, preliminary findings from a larger scale evaluation (300 drivers) of a similar system in Illinois show that, although test participants recommended several human factors improvements, overall the system was helpful in focusing drivers' attention to the presence of an on-coming train.
- **Use of crossing blockage information for traveler information and traffic management:** Simulation of the AWARD system in San Antonio estimated that incorporation of information on crossing blockages into traveler information and traffic management resulted in modest (16%-19%) decreases in travel time delay for affected motorists: a 19% reduction for drivers who followed the system's advice to reroute and a 16% reduction area-wide. Since completion of the AWARD project, additional deployments of this type of system have been initiated in Texas and Minnesota (see below).
- **Second train warning:** Tests of second train coming signs in Maryland and California showed a notable reduction in risky behavior of drivers (36%) and a modest reduction in risky behavior of pedestrians (14%).
- **Four quadrant gate with automatic train stop:** Preliminary findings from analysis of videotaped observations of driver behavior revealed that risky behavior of drivers decreased significantly following installation of a four quadrant gate with automated train stop system in Connecticut.

Emerging Projects

Events in the late 1990's have placed emphasis on two particular aspects of highway-rail grade crossing operations: safety at passive crossings and reduction of inconvenience to the driver through the use of crossing blockage information. Three efforts have recently begun that use ITS technologies to address these problems.

Safety at Passive Crossings

Safety at passive crossings – those without any active warning devices such as gates, lights and bells – has come under increased scrutiny in recent years. In 1998, the National Transportation Safety Board (NTSB) conducted a study of 60 crashes at passive crossings and, based on its findings, issued recommendations to the U.S. Department of Transportation and others.⁵ The NTSB noted in its study that the majority (54%) of crashes occur at passive crossings and that a large portion (60%) of these crashes are fatal.

Two of the NTSB recommendations encouraged the U.S. Department of Transportation (U.S. DOT) to explore further how ITS technologies could be used improve safety at passive crossings. However, all of the ITS technologies for crossings tested to date could not be used at passive crossings with their existing designs because they require electrical power to operate. Passive crossings, by definition, do not have electrical power brought to the crossing itself. Although some passive crossings have power nearby, many of these crossings are in rural areas where the nearest electrical power line is miles away. However, the Minnesota Department of Transportation (Mn/DOT) has initiated a project to specifically address this issue.

- **Minnesota Low-Cost Active Warnings for Low-Volume HRI's:** Building on the success of the in-vehicle warning test and funded by its statewide Guidestar program, the Minnesota Department of Transportation is testing prototype low-cost active warning systems. It is hoped that these warning systems will provide the same capabilities as current active warning systems, but at up to one-tenth the cost.

Mn/DOT has again partnered with Twin Cities & Western Railroad (TC&W) to test a prototype system on 45 crossings on the TC&W line between the Minneapolis-St. Paul and the Minnesota-South Dakota border. A request for proposals was advertised in September 2000. Proposals were received November 2000, and a contract was signed with C3 Trans Systems in Summer 2001, at which time

⁵ The NTSB safety study and recommendations *Safety at Passive Grade Crossings Volume 1: Analysis and Volume 2: Case Summaries* are available online at <http://www.nts.gov/Publictn/1998/SS9802.pdf> and <http://www.nts.gov/Publictn/1998/SS9803.pdf>.

Mn/DOT was in the process of selecting 45 crossings along the TC&W corridor where the system will be installed.

The proposed system will add red light emitting diode (LED) flashing warning lights to crossbuck signs. These flashers will activate when a train is approaching or blocking a crossing. The system will use wireless communication, and will employ digital radios, computers, and global positioning systems to track train location and speed. Field devices at the crossing will be operated by solar and/or battery power and are designed to use existing infrastructure with little or no modification. The primary advantage of the proposed system is the substantially lower installation and maintenance cost when compared to existing traffic control devices at active crossings.

Full-scale operational testing is expected to begin Fall 2001.⁶ Additional testing will include the impacts on driver behavior of variable message signs and active yellow LED warning lights mounted on advance warning signs installed on roads approaching the crossing.

Minimizing Delay for the Driver

Like safety at passive crossings, incorporation of crossing blockage information into traveler information, traffic management and emergency management has gained increased importance in recent years. This information is then used to minimize delay for the driver. In the case of passenger vehicles, this improvement results in a reduction in driver frustration. When the beneficiaries of these improvements are fire trucks, police cars and ambulances, these systems can contribute to an improvement in public safety by reducing the travel time of emergency vehicles. Systems similar to the one tested in the AWARD project are being deployed in Minnesota and Texas.

- **Minnesota Moorhead Area Integrated Train Detection and Traffic Control System Project:** Funded by its statewide Guidestar program, the Minnesota Department of Transportation is testing a system that uses non-intrusive sensors to detect the presence, speed and length of trains approaching designated crossings, and then calculate the duration of blockages. The purpose of this project is to develop an integrated train detection system so that special timing plans can be selected when trains are approaching and when trains are present.

An average of 70 trains per day pass through the test site in Moorhead, Minnesota, and the tracks intersect with many local and arterial streets at at-grade crossings. The average blockage time is four minutes at each intersection,

⁶ For more information about the project, see Mn/DOT's web page for the project <http://www.dot.state.mn.us/guidestar/lowhri.html>.

for a total of about 4.7 hours per day. The current traffic signal system has only a few intersections with localized railroad preemption capability. The project aims to increase safety, reduce response time for emergency vehicles, and reduce delay for motorists. Project partners include Mn/DOT; the City of Moorhead, Minnesota; the City of Fargo, North Dakota; the Fargo-Moorhead Council of Governments; the Otter Trail Valley Railroad; and the Burlington Northern Santa Fe Railroad.

An initial scoping report was completed in June 1998.⁷ A deployment demonstration of video-based train detection, wireless communication and a host-end system was concluded December 2000, and an evaluation report on the performance of this prototype system is available.⁸ Expansion of the project – to include multiple detection sites, interface with traffic signal systems to implement alternative timing plans, and a graphical user interface to provide emergency vehicle dispatchers with real-time information – is currently underway and is expected to be fully operational in late 2001. A third phase of the project, which has not yet been scheduled, includes expansion to additional detection sites and possible installation of variable message signs informing motorists of when and how long the crossing will be blocked.⁹

- **Texas RailView:** The Texas Transportation Institute TransLink laboratory at Texas A&M University is implementing a system similar to AWARD that informs motorists and others of the expected duration that a crossing will be blocked. Several crossings along the Wellborn Road corridor in College Station, Texas near the university campus have been equipped with Doppler radar sensors that detect the presence, speed and length of an on-coming train, from which the duration of crossing blockages can be calculated. This information, along with real-time video of the crossings, will be transmitted to a computer display at Fire Station #4 of the City of College Station Fire Department, in order to allow fire trucks to take alternative routes to avoid delay. This phase of the project is expected to be complete in late 2001 or early 2002. This project is being funded as part of the Texas Transportation Institute's Congressionally designated ITS program that has been on-going since the early 1990's.

A website has been operational since 2000 that displays the status of the rail corridor and shows real-time video of one crossing to anyone willing to download

⁷ The scoping study *Moorhead Area Integrated Train Detection and Traffic Control System: Scoping Study* is available online <http://www.dot.state.mn.us/guidestar/pdf/moorheadreport.pdf>.

⁸ The evaluation report *Moorhead Area Integrated Train Detection and Traffic Control System: Phase One Project Report* is available online at <http://www.dot.state.mn.us/guidestar/pdf/moorhead1.pdf>.

⁹ For more information about the project, access Mn/DOT's web page for the project <http://www.dot.state.mn.us/guidestar/moorhead.html>.

the RailView software.¹⁰ Ultimately, TransLink researchers envision users of the system to include the university transit system, who would use the information for routing their buses during special events, and the city traffic department, who would incorporate train movement information into their traffic signal timing operations.

¹⁰ The website address is <http://railview.tamu.edu>.

Conclusion

The Fox River Grove crash in 1995 focused nationwide attention on the idea of using innovative ITS technologies to improve safety and mobility at highway-rail grade crossings. At the Federal level, several modal agencies within the U.S. DOT initiated programs, put policies in place, and distributed funds to encourage states and municipalities to test these new ideas. Projects initiated prior to and following the Fox River Grove crash are profiled in this report.

The evaluation results from these projects are positive; the ITS technologies tested do make a difference in improving safety and mobility at grade crossings. Local partners are building upon their own work and the work of others in continuing testing of the ITS technologies profiled in this report, as well as systems with entirely new capabilities.

Even with the improvements that ITS has to offer at grade crossings, one crash is too many and one motorist or emergency vehicle waiting at a crossing when it could have rerouted is an unacceptable delay. ITS is one of many tools available to help states and municipalities reach their safety and mobility goals.

ITS Resources

ITS Joint Program Office

<http://www.its.dot.gov>

ITS Cooperative Deployment Network

http://www.nawgits.com/icdn/its_hri.html

ITS Electronic Document Library

<http://www.its.dot.gov/itsweb/welcome.htm>

ITS Professional Capacity Building Program

<http://www.pcb.its.dot.gov>

Federal Railroad Administration ITS and the Highway-Rail Intersection

<http://www.fra.dot.gov/o/dev/its/hri/a.htm>

ITS Resource Guide 2001

<http://www.its.dot.gov/itsweb/guide.html>

Operations/ITS HelpLine

Call toll free (866) 367-7487

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400 7th Street, SW
Washington, DC 20590