IDEA

Innovations Deserving
Exploratory Analysis Programs

Safety IDEA Program

Driver Feedback Device for Passive Railroad Grade Crossings

Final Report for
Safety IDEA Project 09

Prepared by:
Neil Lerner, Richard Huey, Jeremiah Singer, & Christopher Monk
Westat
Rockville, MD

December 2006

TRANSPORTATION RESEARCH BOARD
OF THE NATIONAL ACADEMIES

INNOVATIONS DESERVING EXPLORATORY ANALYSIS (IDEA) PROGRAMS MANAGED BY THE TRANSPORTATION RESEARCH BOARD

This Safety IDEA project was funded by the Safety IDEA Program, which focuses on innovative approaches for improving railroad safety and intercity bus and truck safety.
The Safety IDEA Program is funded by the Federal Motor Carrier Safety Administration (FMCSA) and the Federal Railroad Administration (FRA) of the U.S. Department of Transportation. Any opinions, findings, conclusions, or recommendations expressed in this publication are those of the authors and do not necessarily reflect the views of the sponsors of the Safety IDEA program.

The Safety IDEA Program is one of four IDEA programs managed by TRB. The other IDEA programs are listed below.

- The Transit IDEA Program, which supports development and testing of innovative concepts and methods for advancing transit practice, is funded by the Federal Transit Administration (FTA) as part of the Transit Cooperative Research Program (TCRP).
- The NCHRP Highway IDEA Program, which focuses on advances in the design, construction, and maintenance of highway systems, is part of the National Cooperative Highway Research Program (NCHRP).
- The High-Speed Rail IDEA Program, which focuses on innovative methods and technology in support of the next-generation high-speed rail technology development program, is funded by the FRA.

Management of the four IDEA programs is coordinated to promote the development and testing of innovative concepts, methods, and technologies for these areas of surface transportation.

For information on the IDEA programs, look on the Internet at www.trb.org/idea, or contact the IDEA programs office by telephone at (202) 334-3310 or by fax at (202) 334-3471.

IDEA Programs
Transportation Research Board
500 Fifth Street, NW
Washington, DC 20001

Driver Feedback Device for Passive Railroad Grade Crossings

Final Report
Safety IDEA Project 09

Prepared for:

Safety IDEA Program

Transportation Research Board

National Research Council

Prepared by:

Neil Lerner, Richard Huey, Jeremiah Singer, & Christopher Monk

Westat

Rockville, MD

December 2006

ACKNOWLEDGEMENTS

The project team is grateful for the cooperation and support of the Prince George's County Department of Public Works and Transportation and the Frederick County Department of Transportation Engineering during the field demonstration portions of this project. We also appreciate the assistance and thoughtful reviews of the Safety IDEA Committee and program staff.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

EXECUTIVE SUMMARY

This Safety IDEA project designed a prototype low-cost, portable device to provide drivers with explicit feedback about the safety of their behavior at railroad grade crossings. The countermeasure is a portable driver feedback display for temporary applications at passive highway-rail grade crossings. By providing feedback to drivers, the intent is that drivers will use greater caution when approaching passive crossings in the future, thereby reducing crashes. Because the system is designed to be moved from site to site, it is low cost on a per site basis, even though it provides intelligent sensing and individualized driver feedback.

The majority of the approximately 90,000 railroad crossings in the U.S. are passive; they have no gates, barriers or lights. Passive railroad grade crossings typically are located in rural areas with relatively low traffic volumes and relatively low railroad train volumes. Past research has established that many drivers do not behave properly at passive crossings. Drivers tend to approach passive crossings too fast, engage in little and ineffective visual search, misjudge the speed and distance of approaching trains, and fail to cross at a speed that would allow them adequate stopping distance (given sight distance and train speeds). Behavioral analyses have pointed to the lack of feedback to drivers regarding their behavior as part of the cause. They may not even realize they did something dangerous.

The project consisted of two stages. Stage 1 (Technology and Problem Review to Develop Functional Requirements) identified and evaluated related technologies and research literature, examined system needs for conveying a simple, immediately comprehended message, and developed a formal set of functional requirements and performance specifications. In Stage 2 (Develop Prototype), a prototype system was designed and demonstrated and a final report was produced. Refinement into a commercial product and implementation were not part of this project.

The requirements for the driver feedback device/data collection tool were formally described in terms of functional requirements. These functional requirements specify the target capabilities that an ideal system should achieve and they served as the basis for the prototype design. The end product was conceptualized as being composed of seven system components: Vehicle Sensing; Train Sensing; Environmental Sensing; Driver Display; User Interface; Rail Crossing Traffic Data Recording and Storage; and Power.

The system was also described in terms of the systems inputs required to perform the driver feedback and data recording tasks. These were categorized under four groupings:

Static site features: These refer to fixed characteristics of the site, which include the roadway approach and the crossing itself. These would be manually entered by a technician at the time of system set-up.

Dynamic site features: These refer to characteristics of the site that may change over time and will need to be automatically monitored by the system.

Dynamic vehicle features: These refer to the characteristics of the vehicles being detected. They are needed to determine whether (assuming a train was approaching at the maximum speed for that crossing) a given vehicle would safely clear the tracks or be able to stop prior to the tracks.

User-defined constants (or defaults): In order to compute the safety of a given vehicle's approach, it is necessary to have a model of driver behavior and vehicle dynamics. The parameters selected to use in these algorithms may have a significant influence on the outcome decision. While the device should have default assumptions, it may also be desirable to allow the user (roadway agency) to select various constants, based on local conditions, agency practice, desired degree of conservatism, etc.

Functional performance criteria were established for each of the seven system components, as well as for more general attributes. This set of functional specifications provided the basis for subsequent design.

A functional prototype system was designed, constructed, and demonstrated. It uses a real-time video image processing system (incorporating an Autoscope system) to detect and classify vehicles and trains and derive other key information such as speed and deceleration. Key system components include a pan-tilt-zoom camera, digital video recorder, image processor board, data acquisition board, laptop PC, changeable message sign (CMS) trailer, remote communication transceiver, and aerial camera lift. The primary user interface employs a diagrammatic display that allows the user to input all of the key site characteristics and key parameters for the decision algorithms. There are also separate interfaces for Autoscope control and for the digital video recorder. Real time monitoring is provided on the PC screen, which shows vehicle capture and driver display outputs.

The demonstration of the prototype system was video-based and conducted in two stages: a demonstration of the video field recording and system logic and a demonstration of the driver display system. These two demonstrations were conducted at different sites, to afford an optimal demonstration of each. Narrated video demonstration recordings were developed from the field recordings and provided as supplements to this report.

This project demonstrated the feasibility of the operational system although this initial prototype has limitations that require further development. The concept must also be field evaluated to determine the ultimate effects on driver behavior and rail crossing safety. If successfully evaluated, the device will provide highway and rail authorities with another technology to use at passive grade crossings to reduce poor driver behavior and crashes. The prototype system also has the potential to function as a data collection device that can record information about vehicles and trains in the area of a grade crossing without providing feedback to drivers. The Federal Railroad Administration is producing an operational version of the system for this purpose.

IDEA PRODUCT

This project developed a prototype low-cost, portable device that can be used for periodic or spot application at multiple crossings in a region or corridor. It provides drivers with explicit feedback about the safety of their crossings. The approach is modeled on other driver feedback and/or portable display applications already in use, such as speed display trailers, portable CMS, and ramp speed warnings. Drivers can become immediately aware of the hazard potential of their own actions without having to experience a negative event (which is a very rare natural occurrence). Passive highway-rail grade crossings continue to be dangerous sites. By definition, at a passive crossing the burden for safety relies entirely on appropriately cautious behavior from the driver. Past studies have made it abundantly clear that drivers generally do not behave as desired, in terms of speed selection, visual search, and decision making. However, contrary to common stereotypes, studies find the typical problem is not one of intentional risk taking (e.g., trying to beat a train) but rather that people do not have a sense of the risks of their own behavior. Drivers who approach and cross the tracks in an inappropriate way rarely get feedback that they did anything wrong, reinforcing their poor behavior.

The prototype product developed in this Safety IDEA project provides each driver encountering a highway-rail grade crossing with personalized feedback regarding the safety of the their approach to the tracks. A video image processing system captures vehicles, estimates speeds and stopping distances, and based on site features (e.g., sight distance, train speed) determines whether the driver could have safely stopped had a train been coming. After the vehicle has crossed the tracks, a message is displayed to the driver, showing vehicle speed and indicating whether they could have stopped. This type of system provides a new capability to inform and motivate motorists and influence their behavior at subsequent times when the feedback device is no longer in place at that site. To the extent that drivers are traveling too fast because they fail to perceive or understand the risks in their behavior, as opposed to intentional risk-taking, the feedback device can be expected to improve driver behavior. At typical passive crossing sites, a high proportion of the traffic will be local, and so will have multiple opportunities for feedback and the revision of their behavior. The feedback system provides an intelligent device at a low cost on a per-rail crossing site basis because it is used at multiple crossings, being moved from crossing to crossing within a region or corridor. Because the driver feedback device requires the detection, classification, and measurement of vehicles and trains at a crossing, the system can also be devised to provide the additional function of collecting and reporting vehicular and train activity data for a crossing.

CONCEPT AND INNOVATION

The device developed in this project is innovative in the manner in which feedback is provided to the driver. There are current applications of driver feedback now in use, such as speed display trailers, truck rollover warnings, and curve warnings. All of these are traffic control devices which are intended to influence the immediate actions of the drivers that encounter them. The driver feedback device developed here is not a device that will be left in place at a particular site. Rather, it is a portable system that will be located at a given site only for some period, then removed (and presumably returned later on some periodic or as-needed basis). Most of the time, there will be no device in place at a given crossing. Therefore, the purpose of the device is not to control the speed of drivers for the short duration that it is in place. Rather, the purpose is to inform, educate and motivate drivers so as to result in continued improved behavior *after the device has been removed*.

One of the unusual aspects of the device is that the primary information display for the driver occurs *after* the driver has encountered the roadway element (rail crossing) to which the message is related. This is unlike normal traffic control devices which have the objective of influencing the driver's action on every approach. One reason that feedback is not provided prior to the crossing is that unless drivers are given some opportunity to commit their typical speed choice errors, there is no opportunity to provide them with the feedback that they acted unsafely. "Calming" drivers on the approach with temporary measures will not allow them to experience the feedback for the types of errors they may make when there is no speed monitoring system in place. But even if one wished to provide the feedback prior to the crossing (near side of tracks), this would not be feasible, given the display requirements of this device. The speed assessments must be made too close to the crossing to allow for proper placement and viewing time of the CMS display prior to reaching the crossing. The use of a driver feedback display to educate and inform, rather than control traffic, is a unique aspect of this concept, not just for rail crossing applications, but for highway safety in general.

INVESTIGATION

REVIEW OF TECHNOLOGY AND LITERATURE

A literature review, technology state-of-the-art review, and driver focus groups were conducted to determine the feasibility and requirements of a driver feedback device for passive rail crossings. The findings of these activities are detailed in a project interim report (Lerner, N., Singer, J., & Monk, C. (2005). *Driver Feedback Device for Passive Railroad Grade Crossings*. Project SAFETY-09. Prepared for: Safety IDEA Program, Transportation Research Board.). Among the lessons learned were the following:

- CMSs with radar or other speed measurement technologies have been successfully used to present detected speeds to drivers along with messages.
- Research on CMSs in work zones, speed monitoring displays, and curve warning systems has shown that drivers do slow down when given feedback about upcoming work zones, curves, or hills.
- Research shows that displaying detected speeds to individual drivers is effective in reducing speeds and increasing speed limit compliance.
- There is evidence that speed reductions associated with speed monitoring displays may extend longer than the presence of the display, which is an important assumption of the proposed feedback system.
- Data also suggest that speed reductions associated with speed feedback may not diminish over the duration of that system's presence; speed displays can affect drivers traveling significantly over the speed limit even after the system has been in place 2 to 4 months.
- Intermittent enforcement presence increases compliance with speed displays, although speed displays alone do have an effect.
- The literature does not indicate how frequent or how long a feedback system must be in place for sustained benefits to be achieved.
- Feedback messages may include the driver's speed, an indication of the consequence of that speed, and some instruction of what to do next time (e.g., "Slow Down!").
- Although a variety of messages have been used in research and practice, there has been no thorough comparison of the effectiveness of different messages.
- Red and green color coding for negative and positive feedback for unsafe and safe speeds, respectively, could be beneficial to driver comprehension of the messages.

- Feedback messages should be short and uncomplicated.
- Feedback about the safety of a given driver's behavior will have to be presented after the vehicle traverses the crossing, but it will also be necessary to provide some advance signing to orient drivers to the monitoring system and help them associate their actions with the feedback.

FUNCTIONAL REQUIREMENTS

The passive rail crossing driver feedback device has two related purposes: (1) to determine the safety-appropriateness of each vehicle approach to the crossing and provide driver-specific feedback for each motorist; (2) to serve as a rail crossing data collection tool, archiving data about vehicles and trains. Based on the findings from the literature and technology search, focus groups, and analytic efforts, a set of desirable features and functional requirements was developed to guide the design of a prototype system as well as potentially more refined production systems. A given functional requirement might be met through various specific design alternatives. The design choice may be based on performance, cost, portability, the ability to meet multiple requirements, and so forth.

The driver feedback system provides two visual displays to drivers and their functions should be made clear. The "driver feedback display" provides personalized information about the safety of each driver's speed choice on the approach to the crossing. The display itself is located at some point after the vehicle has safely cleared the crossing. This is the key element of the display system, and the only dynamic sign display, but it is not in itself fully adequate. The system also includes an "advance display." This is simply a static sign placed prior to the crossing (typically beyond the Highway-Rail Grade Crossing Advance Warning Sign) that alerts the driver to the presence of monitoring activity around the upcoming tracks. Because it highlights the presence of the crossing and the fact that there is some form of vehicle measurement, the sign serves to promote drivers' attention to the rail crossing and their speed and visual search as they traverse it. Drivers will be more "tuned in" to the situation as they approach the crossing and thus better able to associate their specific action with the later individualized feedback. At some sites the road geometry will not allow the feedback display to become visible/legible until some distance after the vehicle has cleared the tracks and in such cases the advance display sign will be particularly helpful in allowing the driver to better associate what they did with this delayed feedback.

Although driver feedback regarding safety was the primary function of the proposed device, it was recognized that a data collection capability would provide added utility to the product. That feature was not included in the Safety IDEA project. However, because the Federal Railroad Administration (FRA) had a particular interest in a system that might be used as a data collection tool at rail crossings, FRA (with the approval of the IDEA program) provided independent funding to incorporate that feature into the proposed product. Since the FRA portion began later and has a different schedule, the data collection tool aspect is not fully considered in this report. An expanded prototype functional system, incorporating both the driver feedback and data collection tool functions, will be constructed and demonstrated in early 2007 and will be the subject of a separate report for that project. The dual utility of the product further promotes its potential appeal and cost effectiveness. The requirements for a railroad grade crossing data collection tool are addressed in the consideration of functional requirements in this report but are not incorporated into the prototype system.

Component functions

The passive rail crossing driver feedback device can be described in terms of seven component functions:

Vehicle sensing: Each vehicle approaching the rail crossing must be detected and attributes of the vehicle (speed, size, deceleration) must be measured.

Train sensing: The driver feedback function of the device does not require information about train status, other than over-riding the feedback activity when a train is actually present. However, for use as a data collection tool for rail crossing applications, information about train status (occupying crossing, direction, speed) is required.

Environmental sensing: Environmental considerations such as water or ice on the roadway can influence vehicle braking or driver perception capabilities. While not essential to the system, measuring and incorporating these aspects into algorithms would be a desirable refinement.

Driver displays: This includes all static and dynamic sign elements that convey messages to drivers. It includes advance signing as well as displays beyond the rail crossing that provide safety-related feedback to the motorist.

User interface: This is comprised of the input devices (e.g., keyboard, joystick, etc.) and displays (e.g., system status indications, video monitor) used by the technician setting up and monitoring the system.

Rail crossing traffic data recording and storage: The data collection tool function requires storage of information over a data recording period for later download.

Power: There must be a source of power to run the system over the planned operational period.

In addition to these seven components of the system, there is also the requirement for computation and control, which integrates all of these components, defines safety status, and controls output.

System inputs

System inputs are data required in order to compute the safety status of individual vehicle approaches and for rail crossing data recording needs. The safety-appropriateness of a given vehicle crossing will depend on the vehicle's speed and stopping ability, site characteristics that influence stopping distance, the driver's sight distance along the track, and potential train speed. Some of these inputs are fixed for a given site and will need to be manually input at the time of system set-up. Other inputs are dynamic measures that will have to be sensed in real time by the system. The set of desired inputs are listed below. Some of these are desirable but not essential to a functioning system. These optional inputs are noted by an asterisk (*).

Static site features: These refer to fixed characteristics of the site, which include the roadway approach and the crossing itself. These would be manually entered by a technician at the time of system set-up.

- Roadway/crossing geometry
  - Distance to nearest rail
  - Distance to furthest rail
  - Grade
  - Horizontal curvature*
- Sight distance (in the less favorable direction)
- Maximum train speed
- Crossing roughness/hump

Dynamic site features: These refer to characteristics of the site that may change over time and will need to be automatically monitored by the system.

- Train status
  - Occupying crossing
  - Direction

    - Speed
- Visibility condition*
- Road surface condition (e.g., wet, icy)*

Dynamic vehicle features: These refer to the characteristics of the vehicles being detected. They are needed to determine whether (assuming a train was approaching at the maximum speed for that crossing) a given vehicle would safely clear the tracks or be able to stop prior to the tracks.

- Vehicle location
- Vehicle speed
- Vehicle deceleration
- Vehicle size

User-defined constants (or defaults): In order to compute the safety of a given vehicle's approach, it is necessary to have a model of driver behavior and vehicle dynamics. The parameters selected to use in these algorithms may have a significant influence on the outcome decision. Whereas the device should have default assumptions, it may also be desirable to allow the user (roadway agency) to select various constants, based on local conditions, agency practice, desired degree of conservatism, past crash experience, etc.

- Driver perception-reaction time
    - Given vehicle is decelerating
    - Given no current deceleration
- Maximum acceptable braking deceleration
- Minimum acceptable clearance time (from time rear of vehicle clears train dynamic envelope to moment of first potential arrival of train)

TABLE 1 summarizes the inputs and parameters that may be used for safety computations and data recording.

TABLE 1. Required and desirable system inputs and algorithm parameters for safety computations and data recording

CATEGORY	VARIABLE	SOURCE
Vehicle	Speed	Measured
	Distance	Measured
	Deceleration	Measured
	Length	Measured
	Bumper-to-eye distance	Default (for vehicle size)
	Driver eye height	Default (for vehicle size)
Train	Enter crossing	Measured
	Exit crossing	Measured
	Occupying crossing	Measured
	Train speed	Measured
	Train direction	Measured
Crossing characteristics	Crossing designator(s)	User specified
	Maximum train speed	User specified
	Track location	User specified
	Dynamic envelope width	User specified
	Sight distance (lesser direction)	User specified
	Crossing roughness	User specified
	Road grade	User specified
	Road curvature/skew	User specified
Environment	Road surface condition	Measured or default
	Visibility condition	Measured or default
	Illumination condition	Measured or default
Braking algorithm	Max deceleration: non-truck	Default or user-specified
	Max deceleration: truck	Default or user-specified
	PRT – if already decelerating	Default or user-specified
	PRT – not already decelerating	Default or user-specified
	Clearance/safety margin	Default or user-specified
Time	Date	From computer
	Clock time	From computer
System status	Failures/errors	Detected
	Feedback operational?	Detected

CRITERIA FOR SYSTEM COMPONENTS

General device criteria and functional criteria for each component element of the passive rail crossing driver feedback device are listed below. The criteria are proposed for actual commercial products. Not all are necessary or achievable for prototype demonstration and testing systems.

General device criteria

Relation to rail operations: The system should not require any components to be located on the railroad right-of-way and should not require any authorization from or interaction with the railroad operator or rail authorities. It should in no way interfere with rail operations or safety.

Conditions of operation: The device should be operational under both day and night lighting conditions (although night operation may be impractical for the prototype system). If a device cannot meet the set of performance criteria under night conditions, the device should not function at night (no display).

Driver distraction: No aspect of the device, including the driver feedback display, should present a driver distraction hazard. No aspect of the system should obscure or distract from site crossing features or existing traffic control devices nor limit sight distance. The display should not compete for driver attention at the times the driver should be searching for trains. The time available for viewing displays should be adequately long so that there is ample time for the driver to process the message without precluding proper attention to other roadway features.

Vandalism: System elements should not encourage theft or vandalism and should be secured from theft. Criteria for commercial products will have to be more stringent that what is necessary for a prototype system.

Crash fixed object: System components should be located well clear of the roadway unless required for measurement. Any element that could be hit by a vehicle should not constitute a crash hazard.

Failure mode: If there is any failure detected in any system component, the driver feedback display should be deactivated. An indication of failure and system status should be provided in the user interface and indicated in the stored data.

Portability: The system should be readily transported and easily installed. Ideally it will be transportable by a single vehicle. Installation of the device should not require modification to the roadway infrastructure or require any other permanent changes to the site.

Vehicle sensing

Vehicle detection: The system should be capable of detecting individual vehicles at locations within 500 feet of the grade crossing with 95 percent reliability under favorable conditions. While a similar criterion under less favorable conditions (e.g., rain, fog) is ultimately desirable for a final product, it is not essential for a proof-of-concept prototype.

Vehicle discrimination: The vehicle detection technology should be capable of distinguishing individual vehicles in a platoon. Although the roads where the device is likely to be used will not be characterized by high traffic volumes, it is necessary to distinguish “coupled” vehicles both in order to determine vehicle size and for accurate counts with the data collection tool. The system must also be able to discriminate approaching traffic from receding traffic, since only vehicles approaching the grade crossing are of interest.

Speed measurement: The system should be capable of measuring vehicle speeds in the range of 5 mph to 80 mph within ± 2 mph. Some technologies, such as certain radar systems, cannot accurately measure vehicles under 15 mph, which may be inadequate for sites with severe sight distance restrictions.

Vehicle acceleration/deceleration: The system must provide a means to determine whether vehicles are decelerating within the critical approach area. This is essential in order to determine what driver perception-reaction time values to use. If the vehicle is decelerating, the algorithm may assume that the driver is alerted and also likely has a foot on the brake pedal, so that the assumed PRT is appropriately lower than if the vehicle is not decelerating.

Vehicle size: The system should provide a measure or categorization of vehicle length. Vehicle length will be used directly to compute the estimated time it will take for the vehicle to safely clear the train dynamic envelope. Vehicle length will also be used to categorize vehicles for purposes of assigning braking capabilities. Other data may also be used to assist in this categorization (e.g., weight, number of axles, image analysis), but it is assumed that vehicle length will be the most easily-obtained measure. Vehicles should be classified into at least three categories, which can be discriminated based on typical dimensions, including length (AASHTO, 2001): passenger car (19 feet), single unit trucks (30 feet), and larger vehicles (generally 40 feet or greater).

Travel lanes: If there are multiple lanes of approaching traffic, the system must be capable of detecting, discriminating, and measuring vehicles in both lanes. However, the target application for the prototype system will be confined to two-lane roads (i.e., a single approach lane). This will encompass most passive crossing sites with sight distance concerns and greatly simplifies issues of determining the appropriate driver feedback information and display timing. Future consideration of multiple lane approaches may be considered if the initial evaluation of the two-lane road application appears successful and if further analysis indicates there will be a cost-benefit to this.

Train sensing

Train arrival: Sensors should detect the time of train arrival at the crossing

Train clearance: Sensors should detect the time of train clearance of crossing

Occupation of crossing: The state of the crossing (train-occupied or not occupied) should be determinable, whether directly sensed or derived from train arrival and clearance.

Train direction: The train's direction of travel (entering from driver left or right) should be determined.

Train speed: The speed of the train in the crossing should be measured (within ± 2 mph).

Environmental sensing (desirable but not essential)

Road surface condition: The system should be able to detect and categorize road surface condition (dry, wet, icy) or quantify estimated coefficient of friction.

Visibility conditions: The system should quantify or categorize atmospheric visibility.

Illumination: The system should quantify and/or categorize illumination conditions, with a primary objective of distinguishing daytime and dark conditions.

Driver display

Required displays: The system should include two displays: an advance display prior to the grade crossing and a driver feedback display after the crossing

Advance display content: The advance display may be an active or passive sign and should inform approaching drivers that there is vehicle monitoring being done at the rail crossing ahead. A message similar to "RAILROAD CROSSING SPEED MONITORING AHEAD" is tentatively suggested, but specific wording alternatives may be considered in the design stage.

Advance display location: The preferred location for the advance display is shortly after the Highway-Rail Grade Crossing Advance Warning Sign (W10-1), since this indicates to the driver that there is a rail crossing ahead and thus provides context for the advance message regarding monitoring. However, the sign placement should meet general MUTCD criteria for sign location (Section 2A.16).

Driver feedback display content: The driver feedback display should have dynamic (changeable display) components that provide the driver with feedback about the safety of their crossing maneuvers. If the system determines that the crossing was unsafe, the display should include: (1) the vehicle's speed approaching the crossing; (2) an indication that this was unsafe (by statement or by displaying the safe speed); (3) an indication of consequence and/or what to do next time. If the system determines that the crossing speed was within the safe range, the display should include (1) the vehicle's speed approaching the crossing; (2) an indication that the speed of crossing was appropriate; and (3) a general safety message about the need to watch for trains.

Driver feedback display phasing: A one-phase message is preferred, but a two-phase message is acceptable if it meets all other criteria.

Driver feedback display location: The display should not be presented to the driver until the vehicle has safely cleared the train dynamic envelope. From that point, the display must be legible for a minimum of 6 seconds for a single phase display or 10 seconds for a two-phase display, based on 85th percentile speed (or in the absence of site speed data, 10 mph above the posted limit). Thus, for example, if the 85th percentile speed is 50 mph (73 feet per second), the 6 second criterion will require that the display provide a minimum of about 480 feet of visibility distance (6 sec *73 ft/sec + approximately 40 ft to account for larger vehicle length). Display placement should also be consistent with the guidance of the MUTCD and the *Portable Changeable Message Sign Handbook* (FHWA, 2003).

Driver feedback display legibility requirements: The design target for display legibility is 850 feet. This is based on the assumption of a two-phase display (10 seconds of legibility) and a large (45 foot) vehicle traveling at 55 mph. The *Portable Changeable Message Sign Handbook* (FHWA, 2003) indicates that 24-inch high characters are legible at 960 feet (and 18-inch high characters at 720 feet). These estimates, however, may be somewhat conservative. One CMS manufacturer claims that the 18-inch characters on one of their CMSs are legible at 1,200 feet (http://www.addcoinc.com/uploadedFiles/Products/Documents_Library/led_salesheet.pdf).

Driver feedback display distraction: The display should not distract attention from other aspects of the driving task. Because the most critical task for a driver approaching a passive highway-rail grade crossing is to search for trains, the display should not be visible until the vehicle has cleared the train dynamic envelope. This may be achieved through display timing, location, or visual tuning. The display should not result in excessively long viewing times, defined as individual glance times in excess of 1.5 seconds. Available research suggests that excessive glance durations are unlikely if there is adequate legibility distance and the display does not include dynamic elements such as flashing modes or animations.

User interface

Input device: The input device should permit the user to enter all required system parameters and options. It should permit downloading of stored data. The input device should be located at a safe distance from the traveled roadway. Alternately, the input device may be a portable computer that can communicate with the system via direct plug-in or wireless Internet.

System status/errors/failures: The user interface display should indicate the status of the device and indicate any component system errors, failures, or problem status (e.g., low power)

System security: The user interface should only be accessible to authorized personnel.

Rail crossing traffic data recording and storage

Site specification: Data records should specify the site and its status, including the following variables:

- Crossing designation
- Crossing location
- Traffic control devices present
- Feedback display system mode (operational or off)
- System status (failure mode)

- Vehicle records: The data collection system should provide a complete record of each vehicle crossing. This should include the following variables:
  - Location
  - Date
  - Time
  - Vehicle classification
  - Vehicle speed
  - Crossing status (occupied by train/not occupied)
  - Safety status of maneuver
  - Road surface condition (desired, not essential)
  - Visibility condition (desired, not essential)
- Train records: The data collection system should record a complete record of each train crossing. This should include the following variables:
  - Location
  - Date
  - Time of arrival
  - Time of clearance
  - Train direction
  - Train speed (max)
  - Train speed (min)
  - Train speed (mean)
- Data storage: The system should be capable of storing a minimum of 6,000 data records. This is based upon a review of selected state data from the FRA public crossing inventory (FRA Office of Safety Analysis, http://safetydata.fra.dot.gov/officeofsafety). Cumulative frequencies of average annual daily traffic (AADT) for passive crossing sites suggest that about 95% of all passive crossings have AADT's of 10,000 or less. Since data would be recorded for traffic in only one direction of travel, this results in about half of the volume, or 5,000 cases. The target of 6,000 cases is to account for relatively high-volume days. A capacity of 6,000 records would require a daily download for many sites. The ideal target would be a capacity of 35,000 records, to allow weekly download even for the highest traffic volume sites. The FRA data indicate that

about 90% of sites have AADT's of 5,000 or less, hence only 2,500 or less in one direction of travel. Therefore the target design specification could actually be reduced substantially if necessary without losing many cases.

- Data downloading: Data downloading to other media shall be accomplished at the user interface and/or be capable of remote downloading. The data should be in a format that is easily exported/converted into data analysis software programs such as MS Excel and SAS.
- Data reports: It is desirable that basic data summary reports be available at the user interface and that these include:
    - number of trains, and by speed, direction
    - total time crossing is occupied
    - number of vehicles, and by type, speed
    - vehicles by safety status

Power

Power source: The device should be self-powered. Given the rural locations of many passive crossings, there should be no assumption that electrical power will be available.

PROTOTYPE SYSTEM

A prototype system was designed and implemented to demonstrate the feasibility of the proposed final product. It uses a real-time video image processing system to detect, classify, and measure the speed of individual vehicles. Based on vehicle speed and other inputs, the potential of the driver to safely stop before reaching the train dynamic envelope was computed and a driver-appropriate message was displayed after the vehicle had safely crossed the tracks. It is recognized that this initial prototype has not optimized the user interface or information displays, which should be further refined if the concept is found to be effective.

This section describes the prototype system, including both the video-based data recording components (input and processing) and the driver display elements (output). The demonstration of the system is described in subsequent report sections. The system demonstration of the prototype system was video-based and conducted in two stages: a demonstration of the video field recording and system logic and a demonstration of the driver display system. These two demonstrations were conducted at different sites, to afford an optimal demonstration of each. The field recording system was conducted on multilane roadway with substantial highway and rail traffic and was actually a gated-crossing (which is irrelevant for the demonstration). The driver display demonstration was conducted at a rural, two-lane passive crossing representative of the types of crossings where the driver feedback system is foreseen for use. No actual roadway display was presented at the field recording system site (although the selected displays are shown in the interface display). No actual video processing system was in place for the driver display demonstration (the CMS was manually triggered). Narrated video recordings are provided as a supplement to this report. Together, the field recording demonstration video and the driver display demonstration video provide a full illustration of the operational system, as described in this section.

Functions and capabilities

This system is designed to serve two purposes: to provide safety feedback to drivers after they cross passive railroad grade crossings, and to collect data on trains and vehicles that travel through a grade crossing. The system is designed to be portable and relatively easy to set up so that it can be moved to a crossing, set up for a period of time, and then moved to another site. The components used in its design are easily towed to a given site, use relatively standard platforms that have been implemented for other ITS applications, require no access to railroad property, and require minimal road or infrastructure modification to allow them to operate. In this system, video image processing technology is used instead of specialized roadway sensors. By using this technology, a single camera raised above the roadway can capture information about vehicles and trains in the vicinity of the grade crossing. This information can be used to calculate the appropriateness and safety of driver speeds approaching the grade crossing. Drivers can then be informed about their level of safety after they have successfully cleared the tracks by a CMS feedback display located several hundred feet downstream of the crossing. The same video image processing system can also be used to collect statistics on vehicles and trains that pass through the crossing.

The system also provides the capability for video recording. For example, a record of all traffic could be recorded for later manual verification. Video segments could also be recorded based on triggering events (e.g., train entries or high-speed drivers); the system can store a video record of the time period surrounding the triggering event.

Components

The prototype system involves components at the camera site (or data processing site for offline analysis) and at the CMS display location. FIGURE 1 shows a flow chart describing the interrelation of the system components, each of which is described in this section.

Pan-Tilt Zoom (PTZ) Camera: The camera is a weatherproof dome model capable of pan-tilt and zoom adjustments from the ground near the camera mast emplacement (see FIGURE 2) Alternatively, remote control via an internet connection is possible with the incorporation of a communications means back to a central location. For this demonstration, only local control was used. The camera used for this demonstration was controlled at the digital video recorder (DVR) or the attached PC. These items are located at ground level so that once the camera is raised to a proper height, it can be aimed and zoomed to the appropriate field of view for use in capturing the image. Although the camera used for this demonstration was capable of zooming up to 22X, it was left at its widest (i.e., minimum) zoom to capture a large section of the approach road and railroad track for image processing purposes.

Digital Video Recorder (DVR): The DVR, in addition to its function as the interface to the camera controls, captures event-driven and/or overall video coverage data during the course of the data acquisition process (see FIGURE 3). Once the video calibration and testing is complete, the DVR can be configured to capture specific events by setting up “hot zones” within the video. The DVR will only record video when programmed to do so. For example, the system can be configured to automatically record full quality video for a certain portion of the day or it can be set up to only record for 30 seconds before and 30 seconds after a train passes through the intersection. This allows recording of interactions of vehicles around the arrival of a train. The DVR used for this demonstration, unlike a typical video recorder, records strings of images that can be played back individually or through a special viewer application. It is designed for review and analysis rather than video playback. This allows precise control of the image capture rate and storage of a large amount of visual data. The captured images, however, are incompatible with video image processing.

Image Processor Board (IPB): Parallel to the DVR is an IPB. The image processor used for the demonstration system was the RackVision model distributed by Autoscope. The video signal from the camera is sent directly through the IPB. The IPB is designed to convert motion (i.e., particular activations of pixels) in the video image to data events that can be used in determining the length of the vehicle, the vehicle speed, deceleration, and so on. After the site measurement, the image processor configuration is one of the most critical operations to configure the system for data collection. The system design for this

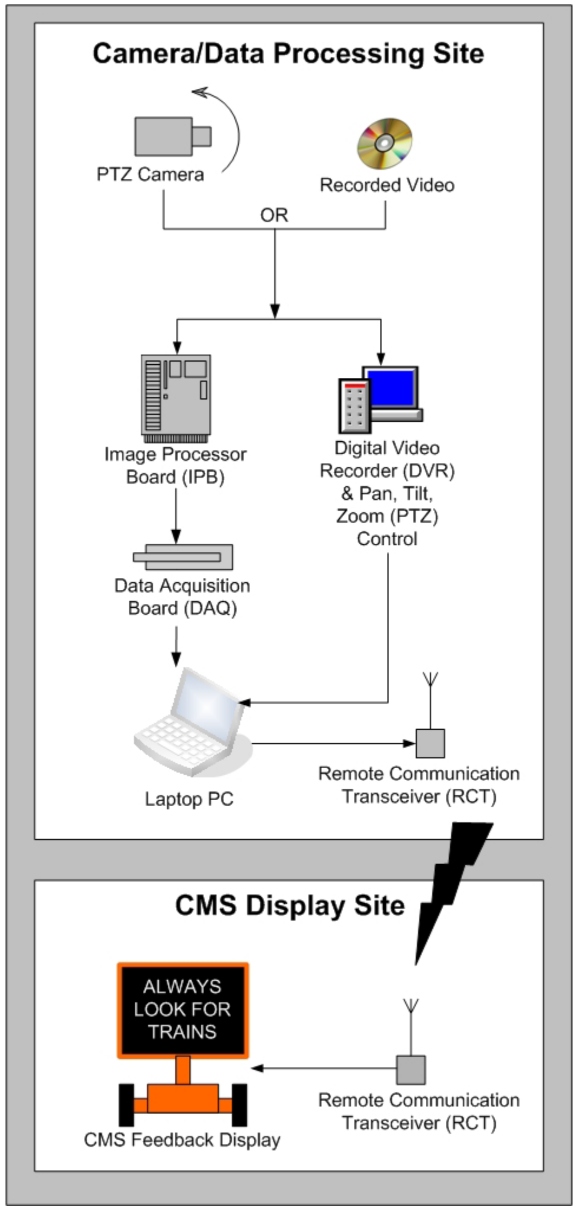

FIGURE 1. Schematic of demonstration system components

prototype uses an initial set of eight virtual sensor locations. These locations within the camera field of view must be adjusted precisely to measure the dynamic parameters of vehicles and trains from the video images. The standard set of eight presence detection areas are designed to be compatible with a variety of grade crossing configurations. They simply must be relocated and calibrated so they can be used to determine the speed, deceleration, and length of vehicles passing through the scene. Multiple measurements of vehicle presence, speed, and so forth, are taken to ensure that data are reliable. After the camera is properly aimed and focused, an image of the site layout is uploaded from the camera to the PC (see FIGURE 4). The virtual presence sensors that have been predefined in the system are then located along the image of the road and the railroad tracks in order to act as the sensors. Four virtual sensors are inserted into the road image approaching the crossing and four other virtual sensors are inserted along the image of the tracks. The use of "virtual" sensors eliminates the need for complicated and costly physical installations of sensors that may be prone to damage, vandalism, and theft. It also eliminates the need to place hardware on or near the railroad right-of-way or in the road.

FIGURE 2. PTZ camera mounted on aerial lift platform

FIGURE 3. DVR display and control interface

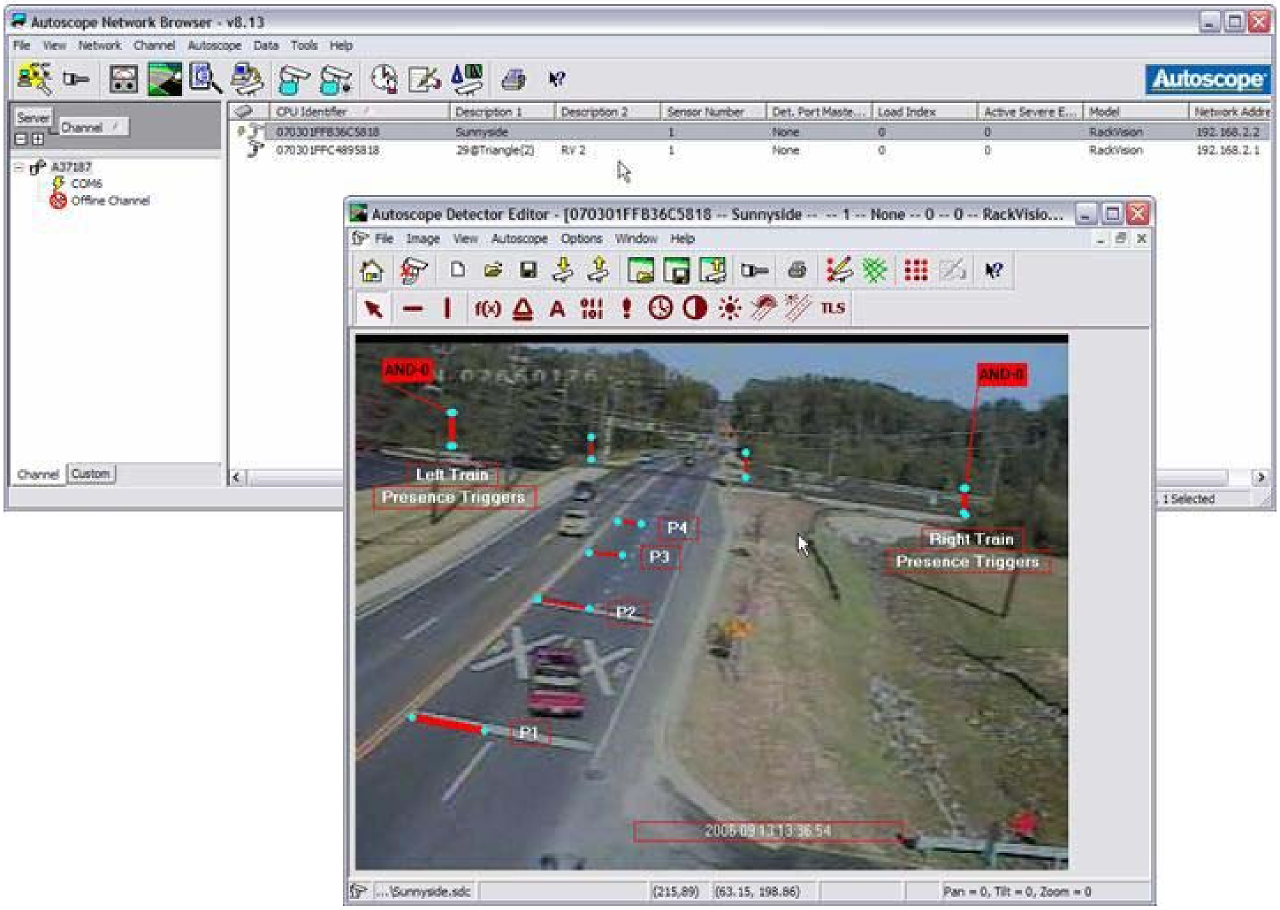

FIGURE 4. Autoscope image processing interface

Data Acquisition Board (DAQ): The IPB includes a set of electronic outputs that would normally be used to control traffic signals and the like for highway intersection emplacements. In this case the outputs are linked to the presence of vehicles and trains as they pass through calibrated locations in the video field of view. Each time a presence detector is triggered by a vehicle or train passing through that area of the image, an electronic signal is sent to the DAQ, which converts the digital event signals from the IPB into signals that can be used by a custom Visual Basic program running on the PC.

Laptop PC: The PC is used to control the pan/tilt and zoom on the camera through the DVR and to configure the DVR for timed or event-based collection of scene images. It is also used to define the sensor zones within the image processor and ensures that they are operating properly for a given site. As well as reading in the data from the DAQ, a Visual Basic program running on the PC collects and interprets those inputs and converts them to measures of vehicle and train dynamics, displays the results for an operator to confirm and validate during setup, and then communicates with the display board so that the information necessary for the driver of the vehicle can be displayed in a timely fashion.

CMS Trailer: The CMS trailer is intended to provide drivers with feedback after proceeding beyond the grade crossing. The CMS used for the demonstration was manufactured by 3M (model PCMS-4) and messages were displayed using shuttered retroreflective yellow green sheeting with embedded LEDs (see FIGURE 5). The sign matrix allowed three rows of text with up to eight characters in each row. Each character was 18 inches tall, which is consistent with MUTCD guidance. The total message display area was 7 feet tall and 10 feet wide. For a deployable system, the control signals for this component would come from the video capture trailer location, which may be more than 1,000 feet from the CMS. As such, the CMS must be controlled remotely from the location of the data collection components of the system. Although the CMS used in the demonstration was not capable of remote control, radio control systems are widely available for such communication and control.

FIGURE 5. CMS display with default (blank) display

Remote Communication Transceiver (RCT): The RCT allows wireless control of the CMS from a remote location. This transceiver must be capable of transmitting control messages up to half a mile without a direct line of sight in order for the system to work under the typical conditions at passive railroad crossings. This capability was not tested during the demonstration, but is not expected to pose any significant challenge in system design.

Advance Warning Sign: An advance warning sign is used to alert drivers that their speeds will be monitored near the grade crossing. The static sign message read "RAIL CROSSING SPEED MEASURED AHEAD" in 4-inch tall black letters on a retroreflective yellow background (see FIGURE 6). The sign was 2 feet tall and 4 feet wide, and the bottom of the sign was approximately 4 feet above the ground.

FIGURE 6. Advance warning sign

Power Supply: Power is needed both at the video trailer and the display trailer. At the CMS trailer, where only the feedback display and a radio transceiver will be working, a solar panel will be used to charge the batteries for a battery powered system. Since the default system state is to have no message on the display until a vehicle passes, the power to display the required feedback is relatively low. At the video capture trailer, since the PC, the DVR, camera, and other accessories will be located there, there may be a need for additional batteries, solar panels, and/or a generator in order to fully power the system. The demonstration system used a 1kW generator for power and was adequate for the task of powering the camera recording, using the DVR, and recording video for test purposes on supplemental video hard disk drive recorders. An uninterruptible power supply (UPS) was also used in the demonstration system to ensure that any electrical noise (e.g., spikes, dropouts, or frequency fluctuations) would be eliminated from the system without adverse effect to the functionality. The one kilowatt Honda generator was adequate for powering the whole system over the limited period for the demonstration data and video collection (i.e., consumption of about 0.5 gallon of gasoline in 8 hours of operation), but a fully deployable system should have access to power for longer periods of time. This might require a generator with a larger fuel store. Additionally, use of one or more solar panels could supplement the generator power to stretch fuel reserves to several days.

Aerial Lift: An aerial lift is needed to raise the camera to an adequate height to view passing vehicles and trains within the same field of view. A camera height of 30-40 feet will typically work well for a deployable system. The camera height for the demonstration system was 38-39 feet. The demonstration system used a lift with an articulated arm designed to lift humans (see FIGURE 7), but telescoping lifts with camera mounts may be more appropriate and practical for a final system.

FIGURE 7. Aerial lift holding camera

Software and algorithm

In order for drivers to safely negotiate a passive grade crossing, they must drive at a speed at which they will be able to stop before the tracks if a train is approaching the grade crossing. They must remain capable of stopping safely before the tracks until it becomes clear that they will be able to safely clear the tracks before a train arrives. The major factors that determine whether a driver's actions are appropriate or inappropriate are the characteristics of the grade crossing environment (e.g., sight obstructions along tracks, road curvature, dynamic envelope width, crossing skew, grade), characteristics of the driver and vehicle (e.g., speed, distance from grade crossing, vehicle size, deceleration profile), and the characteristics of trains (e.g., speed, direction of travel). Environmental factors such as precipitation and visibility may also be of interest, but were not included for this prototype system.

The function of the software program is to allow users to enter relevant information about the site and to set default values for certain variables to allow the program to determine whether a particular vehicle approached the grade crossing at an inappropriate speed (one at which the driver could not safely stop in time if a train is approaching the grade crossing) or an appropriate speed (one at which the driver could bring the vehicle to a safe stop before the tracks if a train is approaching the grade crossing). After passing the grade crossing, drivers receive a feedback message informing them of their speed and whether their speed was inappropriate or appropriate. No feedback or assessment is provided when trains are in or near the crossing because the device is intended to provide feedback rather than time-critical warnings. The use of default values in the prototype system is a convenience for the user, but if used without consideration could lead to inappropriate application. The use of default values must be considered further in subsequent product developments.

Custom software written in Visual Basic acts as the processing system for interpreting the interaction between typical train dynamics, visibility of trains by approaching drivers, and the potential trajectories of vehicles approaching the tracks. The software application allows users to enter relevant information about the grade crossing, train characteristics, and certain assumptions regarding driver behavior and conservativeness of safety requirements. The software uses these inputs to determine the appropriate location to measure vehicle characteristics. Each passing vehicle's speed is then compared to its maximum safe speed, as determined by the characteristics of the site, trains, and the vehicle itself, and appropriate feedback is provided to the driver by the CMS display.

User interface

The prototype system has three separate interfaces, all of which are controlled via a laptop PC. The main user interface is the one within the Visual Basic program that guides the user to input all the relevant parameters for documenting the intersection geometry, the visual obstructions at the site, and the location of the video image processing markers used for calculations of distance, speed, and deceleration. The other key interface for making the CMS feedback system operational is the Autoscope interface that is used to adjust the locations of the image processing triggers to capture the vehicle approach and the train presence from the video (see FIGURE 4). The third interface controls the DVR. All the functions and adjustments of the DVR and the camera are accessible via the laptop PC, includes pan/tilt/zoom controls, definition of event recording preferences (resolution, duration, frame rate, etc.), video labeling (if desired), playback, and memory management. Although this interface is not critical for CMS feedback (since camera field of view controls are accessible through front panel buttons as well), video event-driven recording will require some interaction with this interface and adjustment of parameters to capture only the desired periods of time for playback and analysis.

System setup and configuration

Site Selection: The site selection, although driven primarily by a need to measure vehicle speeds and provide feedback at a given site, must be balanced with the ability to set up a CMS after the crossing with adequate sight distance and also the ability to find an appropriate space to raise the camera's aerial lift in the region prior to the crossing. It is important to keep the aerial lift away from power lines to avoid personal injury and damage to the power lines.

CMS Display Placement: The CMS display must be located downstream of the crossing and must provide drivers with sufficient visibility distance to be able to read the CMS messages at expected driving speeds. The exact location of the CMS should depend upon expected driver speeds (higher visibility distances are required at higher speeds) and obstructions to visibility. The display should be visible and legible for at least 10 seconds to allow driver to read the entire message twice.

Site Measurement: Site measurement is necessary to define the field of view for drivers as they approach the grade crossing. Within the Visual Basic program on the PC, users can input the relevant measurement to determine sight distances and safe approach speeds (see FIGURE 8). All of the information about visual obstructions, and the angles and distances that need to be taken for those obstructions, are located within a plan view of the area and can be found within the Visual Basic program.

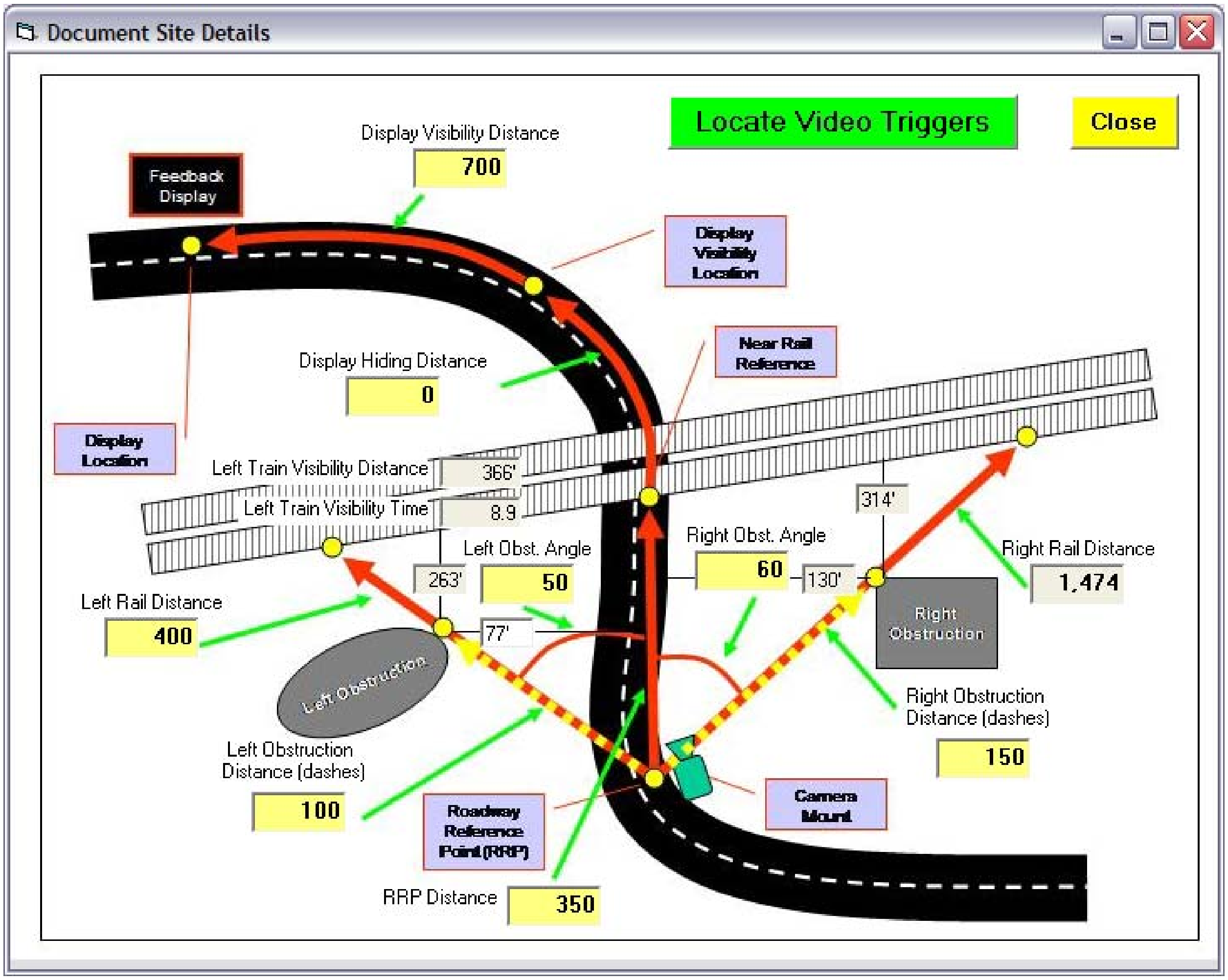

FIGURE 8. Site measurement data entry interface

Video Presence Sensor Placement: Once the site is measured, the camera can be placed at a location that captures the critical point for determining vehicle speed and the driver's ability to stop based on the calculations of the data collection program. The camera's image processing sensor points can then be arrayed to envelop the critical measurement point and the train tracks. The standard sensor locations that the system uses to calculate vehicle and train dynamics must be measured and entered into the data collection program so that their activations are properly interpreted. FIGURE 9 shows the interface used to enter this data. During system development and testing, the vehicle trajectory sensor locations were placed at about 50 foot intervals in the video scene. Because of visual markings on the road (i.e., dashed lane markings), no supplemental markings were necessary. However, if no such markings are available, temporary markings and measurement of them relative to the near rail will be needed to set the markings. Similarly, references for the placement of the outer right and left sensor locations for determination of train dynamics will also be required. Distance from a common reference will be required to properly measure train dynamics and length. Though not as critical as the vehicle sensor locations, the measurements to these points are also important. After providing the measurements to these points, the RackVision IPB must be accessed and the location of the image sensors must be adjusted to correspond to the known locations of the vehicle and train trajectory sensor points within the camera field of view.

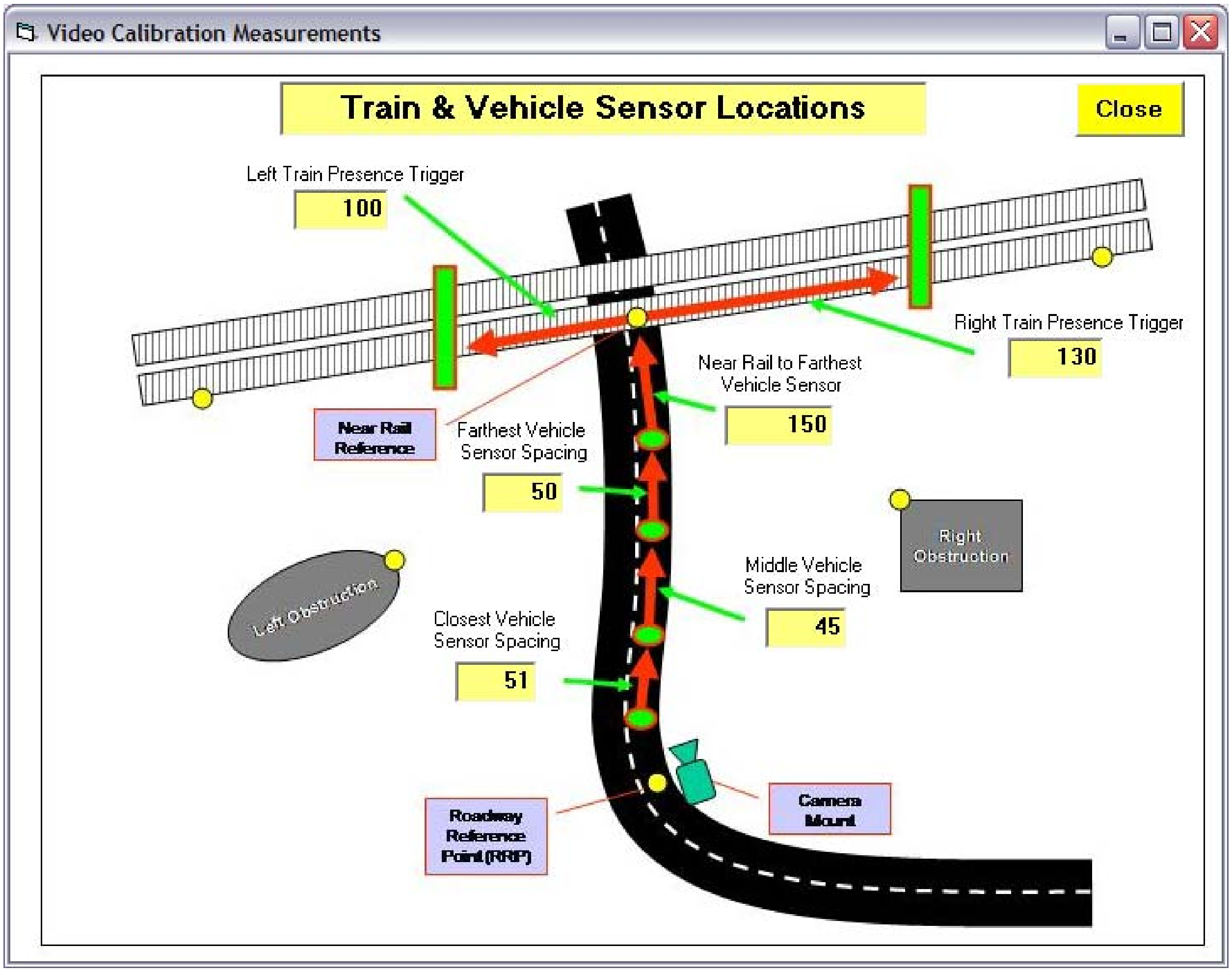

FIGURE 9. Sensor location data entry interface

Data Collection Parameter Entry: Although many of the measurements taken during the site selection process have already been documented, the last step in setting up the site is to place all of the data collection parameters into the Visual Basic program (see FIGURE 10). Within the program, text boxes or drop down menus are provided to allow the user to fill in all of those pertinent details. Once those details are in, the system will document them, capture them to an output files and begin collecting data based on the parameters that are supplied by the user. It is very important to properly document and fill in all the appropriate text boxes so that there is a good record of how the system was setup and exactly what was being collected during a given data collection operation. For the demonstration, a number of the parameters have default values that can be filled in automatically. However, during deployments each of these values should reflect the actual site's configuration.

Crash Protection: The camera mount and the CMS display are trailer-mounted and the safety considerations regarding their location and marking are similar to those associated with other CMS and roadside hardware applications. They should be placed on the shoulder of the roadway, or if practical, further from the traveled lane. Consistent with Section 6F of the MUTCD, the signs and trailers should have the required retroreflective markings. As deemed appropriate, local agencies may choose to use additional delineators, advance signing, or protective barriers.

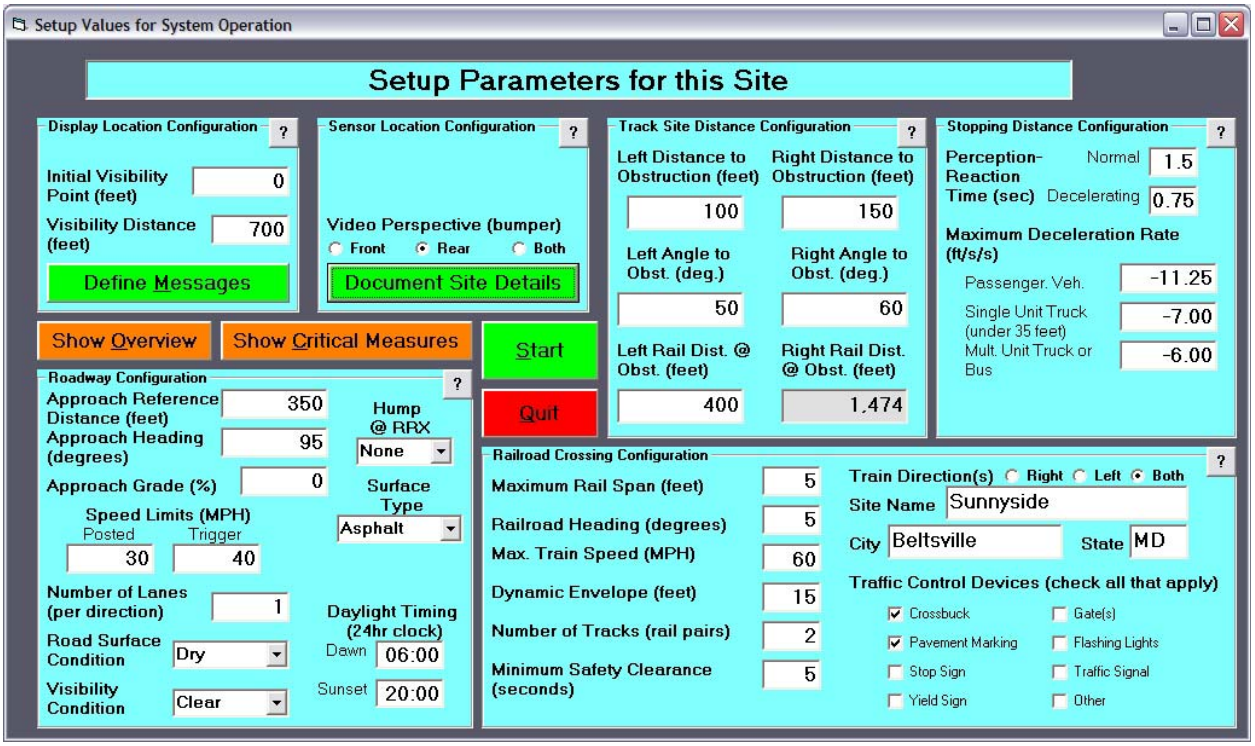

FIGURE 10. Site parameter data entry interface

Operation

Speed Calibration/Testing: After the system is set up, speed calibration and testing should be conducted. For our demonstration and testing we used a laser range finder and speed sensor that would typically be used by law enforcement agencies to measure vehicle speeds. This also allowed for measurement of passing trains and individual passing cars which could then be verified by the feedback in the Visual Basic program to ensure that the measurements and setup parameters were the proper ones for capturing what was occurring in the video scene.

Video/Event Recording: Recording can occur as discussed in the DVR equipment description section. For many applications of this type, it may be of interest to record vehicle crossings that occur very near the time of passing trains. Because of the pre-recording capability of the DVR this can be set up as the only time or one of the select times in which video is recorded. By setting up triggers to allow this to occur, video can be limited to only those times that a train is present and then a few seconds before arrival and after passing. If it is desirable to capture a similar measure surrounding each vehicle's passage, that can be programmed as well. In either case, these are user preference items that can be tailored to the needs of the agency collecting and using the data.

Data Collection: After all the setup parameters have been entered into the Visual Basic program, it will be possible to monitor the activity at the railroad crossing via the PC interface. The computer program is designed to monitor every passing vehicle to determine the pertinent dynamic factors associated with that vehicle, including the size, speed, and deceleration characteristics of the vehicle, as well as the count. The same information, with the exception of deceleration characteristics and the addition of direction, is collected and fed back to the user for passing trains. Each of those passing vehicle or train events will then be recorded to a file that documents when vehicles passed, how fast they were going, and under what interactive conditions (e.g., able or unable to stop or clear the tracks) those events occurred.

Status Monitoring: Status monitoring is provided by the Visual Basic program. The PC screen displays relevant train and vehicle measures as they occur so that an operator can verify the data displayed by the system. This allows operators to refine the configuration if there are errors or if the system is not sensing the appropriate stimuli. The condition of the CMS display is also shown on the PC screen. Even though the user may be watching the vehicles pass from a point near the camera location, he or she will likely not be able to see the CMS display because of its remote distance. However, the information on the CMS can be seen and verified at the status monitoring display.

Data Reporting: Data reporting is intended to provide an overview of the data collected during a given period of time. This function is not provided automatically at this point but the data saved by the data collection system is in ASCII format with comma separated delimiters so that it can be exported to Excel, Access, or some other data manipulation program to allow review of summary data in a variety of different formats and enable it to be grouped by a variety of different parameters.

Maintenance

Data Downloading: Data collected on the PC can be downloaded through a variety of different removable media by connecting a portable hard drive, burning a CD or DVD on the PC itself, or connecting to a network to download the data. The DVR also has the capability to connect to an external hard drive and to export that data for use by various other systems.

Storage Management: Each vehicle or train observed by the system constitutes one record in a data file. Each record contains numerous data points. Those records are all in ASCII files using a comma separated value form and can be downloaded as a .CSV file from the PC to view in a tabular format. Each record requires a very small amount of PC disk space for storage, so typical PCs should be able to store more than one month of data, even at sites with relatively high traffic volumes. The size of the data files on the DVR will be much larger because they are .JPG image files and, depending on the frequency of capture, may be created at a rate of up to 60 images per second for high speed data collection. Those files can then be put onto a hard drive. When the DVR runs out of space, it overwrites the oldest data on the hard drive. As such, periodic downloading and cleanup of the hard drive within the DVR will be necessary.

Power Replenishment: Power required for the camera and the CMS display can be supplemented by solar panels to provide a continuous power source. However, the location of the PC and the DVR at the camera location will likely require a more substantial power source because solar power may not be adequate to handle the power requirements for those extra components. During the video recording demonstration, a one kilowatt generator supplied the power necessary to handle those power requirements. Gasoline powered generators, however, require occasional refueling. For more continuous operations, a revised generator solution (i.e., larger tank, automatic ON/OFF, etc.) will be necessary.

FIELD RECORDING DEMONSTRATION

Sample video was recorded at a grade crossing in Beltsville, Maryland. The purpose of this exercise was to allow the project team to explore image capture locations and angles and to record video for use in defining detection and measurement algorithms for vehicles and trains. The video was also used to demonstrate real-time vehicle measurement and classification and to trigger message displays.

Video was recorded using a camera fastened to the bucket of a Genie TMZ-34/19 aerial lift (see FIGURE 11). The lift was located on the roadside, approximately 20 feet from the nearest traffic lane. The lift arm was extended to its maximum height, which raised the camera to a height of 37 feet above the ground. The camera was remotely aimed toward the roadway and the grade crossing. FIGURE 12 shows the camera view from extended lift. Vehicles were observed as they approached the grade crossing from the bottom of the video frame.

FIGURE 11. Aerial lift with camera, shown with lift arm retracted (left) and extended (right)

FIGURE 12. Camera view of grade crossing with occupying train

The site used for video recording was an actively controlled grade crossing with gates, lights, and bells. The road was a suburban arterial in Beltsville, Maryland, with four lanes of traffic; two lanes in each direction. The speed limit on the road was 30 mph. The road and the tracks intersect at a right angle. FIGURE 13 shows an aerial image of the grade crossing site with the road on the horizontal axis and the railroad tracks on the vertical axis. Driver visibility along the tracks is limited by a building (the light gray roof is visible at the top of FIGURE 13) and trees on the left side of the road and by trees on the right. Train speeds typically range from 45 mph to 65 mph. Although the driver feedback device is designed for use at passive grade crossings on two-lane roads, this site was ideal to demonstrate video capture and processing capabilities because it had frequent train traffic and a mix of many vehicle types.

FIGURE 13. Aerial image of grade crossing (from Google Maps)

Video was first recorded from a distance of 225 feet from the nearest track. Video was recorded for approximately 1 hour (10:30 AM to 11:30 AM) at this location. Four trains passed through the grade crossing during this time. The aerial lift was then moved to a distance of 358 feet from the nearest track. Video was recorded from this location for approximately 5 hours in the afternoon (12:00 PM to 5:00 PM) and again for approximately 3 hours in the evening (7:30 PM to 10:30 PM). Six trains passed during the afternoon recording and four passed during the evening recording. Video was collected again the following morning for approximately 1 hour (7:30 AM to 8:30 AM). Four trains passed the grade crossing during this time.

The field recording was used to develop a video demonstration of the data acquisition and processing algorithm. The video is provided as a supplement to this report. The narrated video demonstrates the program setup process and contains illustrative clips of traffic and the corresponding system response as displayed on the user interface.

DRIVER DISPLAY DEMONSTRATION

The research team conducted a demonstration of the driver display component to illustrate what drivers would see as they pass through the grade crossing and approach the driver display. All of the displays that a driver would experience were set up on a road with a grade crossing and the research team drove a vehicle through the test site at calibrated speeds to simulate the experience of drivers as they approach a passive grade crossing, cross the tracks, and approach the CMS with the feedback message. For this demonstration, the CMS display was manually triggered to simulate the timing of the automated system. The demonstration drives were recorded on video from the driver's perspective. A narrated video demonstration is provided as a supplement to this report.

The site used for this demonstration was a two-lane rural road with light traffic in Walkersville, Maryland. The road intersected a passive grade crossing that had a Crossbuck (R15-1), a Highway-Rail Grade Crossing Advance Warning (W10-1) sign, and advance pavement markings (as shown in MUTCD Figure 8B-6). This section of track no longer carries train traffic, which makes the site an ideal location to demonstrate the display component under a variety of driving conditions. FIGURE 14 shows a map of the road and the railroad tracks. For the demonstration, the test vehicle traveled on Glade Rd from the upper left of FIGURE 14 to the lower right. The approach to the grade crossing was straight and level for about 1,000 feet. Upon crossing the tracks, the road curved to the left, then to the right, then was straight for more than 1,000 feet. The transition from the curved section of road to the straight section occurs about 380 feet beyond the grade crossing, which is also where the driver's line of sight expands to more than 1,000 feet.

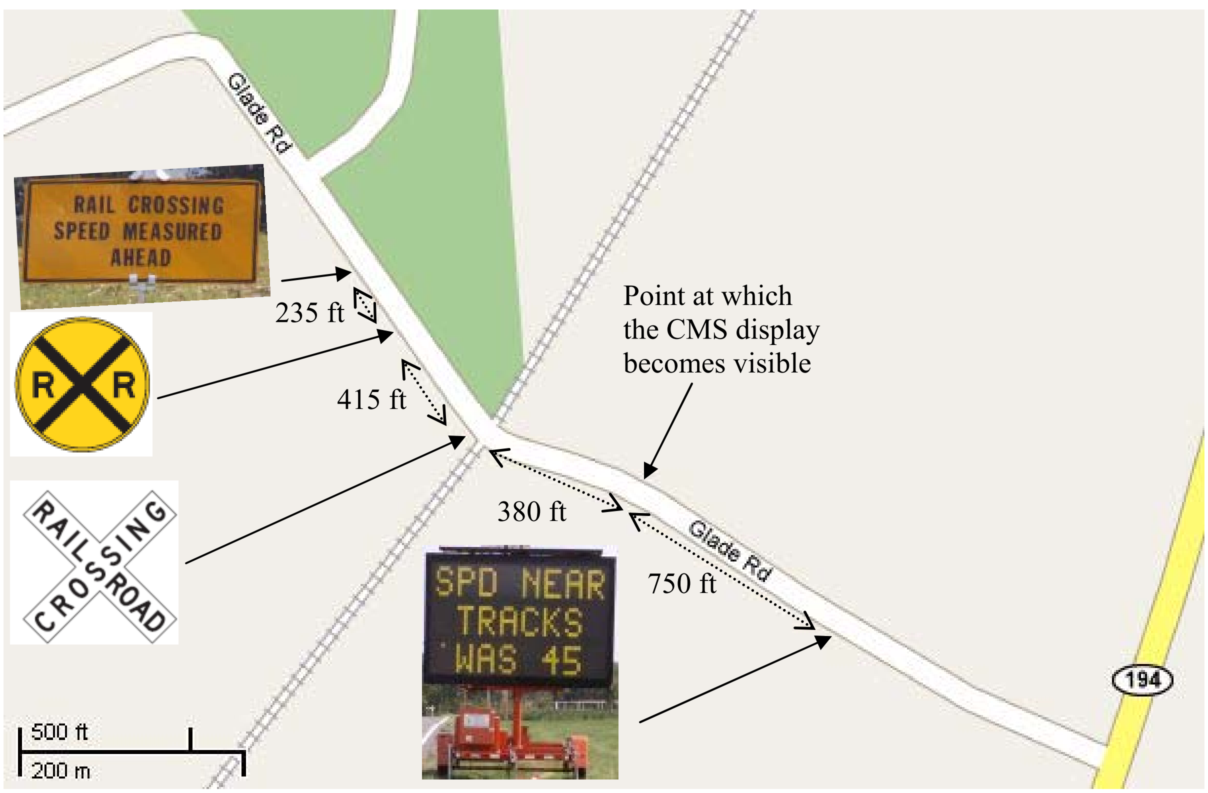

FIGURE 14. Map of demonstration site (from Google Maps) showing sign locations (to scale)

Displays

An advance sign was created to alert drivers to the presence of speed monitoring equipment on the approach to the grade crossing (see FIGURE 15). The sign was placed on the roadside approximately 650 feet before the grade crossing and 235 feet before the Highway-Rail Grade Crossing Advance Warning (W10-1) sign. The sign shown in FIGURE 15 illustrates the wording and location of the advance sign. However, larger letter size than shown in the example may be desirable for field use.

FIGURE 15. Advance sign display

A portable CMS was used to display feedback messages to drivers downstream of the grade crossing (see FIGURE 16). The CMS was located 1130 feet beyond the grade crossing and provided 750 feet of unobstructed visibility. This viewing distance was required to provide the minimum 10 seconds of sign viewing time for higher speed vehicles at this site. The CMS displayed two-phase messages to approaching drivers (see FIGURE 17). The first phase of the message was "SPD NEAR TRACKS WAS *XX*" (where *XX* is the vehicle's actual speed approaching tracks). The second message phase was conditional upon the appropriateness of the driver's speed. If the driver's speed was inappropriate, the message read "CANT STOP FOR TRAINS." If the driver's speed was appropriate, the message read "ALWAYS LOOK FOR TRAINS." A 3-second display phase duration was used. The MUTCD specifies a minimum phase duration of 3 seconds with adequate viewing distance to allow the message to be read "at least twice at the posted speed, the off-peak 85th percentile speed…, or the anticipated operating speed." Assuming an operating speed of 40 mph (10 mph above the speed limit), drivers would have 12 seconds to view the CMS display. A 3-second phase duration provides sufficient time for these fast drivers to read both message phases two times.

FIGURE 16. CMS downstream of grade crossing

Appropriate Speed Message **Inappropriate Speed Message**

FIGURE 17. Messages displayed by the CMS

In addition to the advance sign and the CMS, the research team also placed portable WORK AREA AHEAD signs approximately 800 feet prior to the demonstration area on both approaches to the grade crossing. These signs are not part of the driver feedback system, but were used to alert approaching motorists to the presence of the research team.

Demonstration drives

The research team conducted demonstration drives through the test site to experience what actual drivers would see as they approach the grade crossing, pass through it, and approach the CMS display. A video camera inside the vehicle recorded each drive from the driver's point of view. Each drive began approximately 0.5 mile before the grade crossing and ended shortly after the driver passed the CMS display.

The driver drove through the site at 30 mph, 40 mph, and 45 mph. The messages on the CMS display were configured for each drive speed, so the CMS informed the driver of his speed approaching the tracks and the appropriateness of that speed (see FIGURE 17). 30 mph was considered an appropriate speed while 40 and 45 mph were considered to be unsafe. CMS display phase duration was set to 3 seconds. For this demonstration, the messages were triggered by a member of the research team as the driver came into view of the CMS display. For a final system, the CMS display would be activated by the vehicle detection component using an algorithm to estimate when vehicles will come into view of the CMS.

The drives indicated that the CMS display provided sufficient legibility for the driver to read messages from the maximum sight distance of 750 feet that was available at the demonstration site. With a 3-second phase duration, the driver could read the entire two-phase message two times when driving at any of the three speeds.

PLANS FOR IMPLEMENTATION

The prototype driver feedback system functions reasonably and the application appears feasible, but the system is not yet refined enough for implementation. Several steps are required to bring it to that point.

First, the device needs to be further refined in terms of day/night and all weather capability, precision/reliability, camera mounting structure, vandal-proofing, and so forth. Installation and use need to be made user-friendly, so that the system can be implemented by highway personnel quickly and with minimal training. Once the system has reached this stage, it will then be necessary to conduct a field evaluation. This is a novel device for use on the roadway and its benefits must be demonstrated. Such an evaluation would typically employ a “before/after with control site” design. It should include dependent variables such as approach speed and speed profile, speed at crossing, driver looking behavior, and driver decision outcomes (e.g., probability of stopping as a function of time to train arrival, vehicle-to-train clearance times). Because of unique issues for certain vehicles, the evaluation should include separate consideration of system benefits for passenger vehicles, and larger vehicles (e.g., trucks, and buses). Ideally a field evaluation also would be able to systematically investigate the patterns of use that would maximize the improvements in driver behavior: how long the system should be installed at a given site, how frequently it should be re-introduced, should there be associated police presence, and so forth.

The field evaluation might also benefit from interviews conducted with some of the motorists who will be provided with the feedback. This could help assess whether the feedback made an impression strong enough to change motorist actions when approaching the crossing. It could also provide an opportunity to confirm whether drivers understood the message, if they found it credible, if they were confused about anything, if they had suggestions for improvements, and so forth.

Once the system has been field evaluated and assuming it merits commercialization, a final version of the product must be produced, incorporating lessons learned from the field evaluation and with attributes required for actual field use: durability, storability, portability, vandal resistance, proper failure modes, and so forth.

Once the device is field-ready and demonstrated, information about it may be disseminated through presentations at professional meetings, published reports, conferences, and trade shows. Contacts may be made with equipment manufacturers, the railroad industry, and state or local traffic authorities, to promote application and commercialization.

Though the prototype system was designed to deliver feedback to drivers, it also has the potential to record information about vehicles and trains in the area of a grade crossing without delivering feedback to drivers. For this purpose, the system would function very much like the current prototype, but would not require a changeable message sign or any of the other components required to deliver feedback. The Federal Railroad Administration is producing an operational version of the system for this purpose.

CONCLUSIONS

The results of this Safety IDEA project demonstrate the feasibility of a portable driver feedback system that can inform motorists of their unsafe behavior at passive highway-rail grade crossings and potentially motivate proper speed selection on future trips. The prototype demonstrates that a relatively low-cost, transportable system, using real-time video image processing, can capture the desired inputs and provide individualized feedback to motorists passing through a rail crossing site. This project developed and demonstrated the prototype but did not assess the actual effectiveness of the system for modifying motorist behavior. That will require subsequent field evaluation.

The project developed an extensive set of functional specifications for a final product. This set of specifications may be useful to others in the transportation community who wish to explore related devices, whether for highway-rail applications or other highway safety concerns. Although simple driver feedback devices have been used and proven useful in other situations (e.g., speed display trailers, curve warnings), the concept of using intelligent feedback as an instructional tool to inform drivers about their errors under conditions where they may be misperceiving the situation is new. Such a driver feedback system may help overcome the negative effects of benign feedback, undesirable local traffic norms, and social pressure from other motorists.

One of the complexities that emerged in the course of the work was the demand of constructing and properly locating an appropriate feedback message to motorists. The need for a short, simple, highly legible message conflicts with the need to convey a complex conditional concept (at the speed you were going, if a train had been coming, you may not have been able to stop your vehicle before reaching the tracks). The need to delay presentation of the message until the motorist has successfully cleared the tracks conflicts with the desire to locate the display near the tracks, in order to strengthen the association. The solution offered in this project is a system that includes a static sign in advance of the `crossing (to promote driver attention to the crossing and their speed, and to help them associate the feedback display with the preceding rail crossing) and a two-phase changeable message sign for feedback after the crossing.

Now that a working prototype system has been demonstrated, the next step on the path to implementation is to refine the device into a product that potential users feel is complete, easily usable, accurate and reliable. The system must then be field evaluated, both for usability and safety effectiveness.

INVESTIGATOR PROFILE

Neil Lerner, PhD
Manager, Human Factors
Westat
1650 Research Blvd
Rockville, MD, 20850

Phone: 301-315-5962
Fax: 301-610-5128
Email: lernern1@westat.com