Railroad-Highway Grade Crossings
A Look Forward

FRED COLEMAN III, *University of Illinois at Urbana-Champaign*

In Cooperation With:
RONALD W. ECK, *West Virginia University*
EUGENE R. RUSSELL, *Kansas State University*

The Committee on Railroad-Highway Grade Crossings is concerned with the safety and other affected characteristics (including economic considerations, traffic flow and delay, and countermeasures) of both highway and rail traffic at points where they intersect at grade, including the proximate surrounding environment and rail transit facilities.

This is a white paper on the state of the art and the state of the practice on railroad-highway grade crossings with a look to the future. In order to look to the future and understand where we are today, it is important to recognize that grade crossing safety is and has been an evolutionary development of operating practices, laws, and institutional responsibilities. Then and now, their purpose is to make the interaction between trains and vehicles at grade crossings as safe as possible while acknowledging and minimizing adverse impacts to other characteristics. Engineering and operating practices from the highway and rail modes alone cannot achieve the level of safety desired. Education of the public and enforcement of laws to encourage desirable driver behavior are also major factors. Therefore, organizations such as Operation Lifesaver and law enforcement agencies have key roles today and in the foreseeable future. Because of length limitations, this white paper will not address pending federal or state legislation as it applies to this discussion.

Passive traffic control devices provide static messages of warning, guidance, and in some instances, mandatory action for the driver. Active traffic control devices are those that give warning of the approach or presence of a train. They are activated by the passage of a train over a detection circuit in the track. Active control devices are supplemented with the same signs and pavement markings that are used for passive control.

RAILROAD ACTIVITIES AND SAFETY

State of the Practice

In all states an audible warning provided by a train's horn is required on the train's approach both to at-grade crossings with active warning devices and to crossings with passive warning devices. This practice is a long-standing operating rule of railroads. A whistle post located alongside the tracks is the stimulus to the train engineer to sound the horn. The location of the whistle post varies from 300 to 1,800 feet before the crossing.

Train headlights on the leading engine are also utilized to provide track illumination for train engineers but also to improve the visibility of the train to motorists. Train headlights are required to be on whenever the train is in motion. Ditch lights are additional lights placed on both sides of the lead engine to improve the visibility of the train to drivers. In 1995 they were required on all new engines and became mandatory on all engines after 1997.

Look to the Future

Alternatives to the use of train horns to provide audible warnings to drivers have recently been investigated. Environmental noise impact is the issue. Use of the horn is required under railroad operating rules; Federal Railroad Administration (FRA) guidelines require 96 db (A) at 100 feet in front of the locomotive. Research on train horn relocation to the grade crossing and improved directional control of the sound has been conducted. Results suggest that this may be a viable alternative to address noise concerns and provide an expected safety warning.

Enhancing rail car visibility in low light conditions by adding to or increasing retroreflective material on the sides of rail cars is designed to aid drivers' recognition of blockage of crossings under these conditions. Evaluation in controlled laboratory conditions indicates sufficient promise for field testing to proceed. Headlight patterns that include additional lights placed in strategic locations are being evaluated to determine if driver perception of train size and movement are changed and, if so, whether a safety benefit results. Results from early studies in this area indicate that drivers recognize the presence of a train better. The question of whether improved perceptual recognition will translate to improvements in driver behavior and accident reduction has not been resolved.

HIGHWAY USERS

State of the Practice

Passive Traffic Control Devices

Signs and markings as traffic control devices that provide a static message of warning and guidance along highways approaching and at railroad crossings at grade are intended to work as a system to permit safe and efficient operation at crossings. The specifications and guidelines for usage are detailed in the national *Manual on Uniform Traffic Control Devices* (MUTCD). All signage and markings are retroreflective.

The railroad Advance Warning sign is used to alert motorists that they are approaching a crossing. The sign is round (36 in. in diameter) and is the only warning sign that is not diamond-shaped like other related advance warning signage used to indicate that roadways are parallel to crossings. An appropriate Advance Warning sign is required except under specified restrictions as provided in the MUTCD.

The Railroad Crossing (crossbuck) sign is defined as a regulatory sign in the MUTCD. Signs in this category inform highway users of traffic laws and regulations and the applicability of legal requirements that would otherwise not be apparent. The primary purpose of the crossbuck sign is to identify and direct highway users' attention to the location of an at-grade crossing. Legal obligations imposed upon the driver relative to behavior or conformance are minimal. A crossbuck sign on each approach is required at all at-grade crossings. Jointly used with the Advance Warning sign and pavement markings, these form a passive traffic control system.

Pavement markings in advance of a grade crossing are placed to form an X and include the letters RR in current practice. However, MUTCD guidelines do not require their installation at grade crossings where an engineering study indicates that other devices provide suitable control. MUTCD guidelines require their placement on approaches where grade crossing signals or automatic gates are located and at all other grade crossings where the prevailing speed of highway traffic is 40 mph or greater as well as where engineering studies indicate a significant potential conflict between vehicles and trains.

Illumination at grade crossings should be implemented when an engineering analysis determines that better visibility of the train is needed. Factors considered are substantial railroad operations at night, slow train speeds, crossings blocked for long periods, or accident history indicating that highway users are having difficulty seeing trains or traffic control devices during hours of darkness.

The stop sign is a regulatory sign requiring mandatory action by motorists and is unchanged in shape and color when placed at railroad-highway grade crossings. Its use should be limited to grade crossings where a detailed engineering study has established a need for this regulatory sign. The MUTCD identifies crossing characteristics for such sites; however, the use of stop signs is suggested as an interim measure until active traffic control devices can be installed.

Active Traffic Control Devices

Flashing-light signals either mounted on posts adjacent to the roadway and tracks or cantilevered across approach lanes are the first level of active warning devices used to inform highway users and pedestrians of the approach or presence of a train. The actions to be taken by motorists when the signals are activated depend on motor vehicle code laws and regulations; however, at a minimum, stopping and looking before proceeding are required. Two incandescent bulbs in a horizontal line with mirrored backing are focused through either 8-in. or 12-in. red lenses, and the entire unit is contained in a hooded black housing. The lights flash alternately 35 to 65 times per minute. All passive signage and pavement markings are included on the approach to crossings with flashing-light signals. Train volume, highway traffic volume, accident history, and geometrics are all used in an engineering study to determine the need for flashing-light signals.

Automatic gates are traffic control devices used as an adjunct to flashing lights. The gate arms and flashing-light signals operate together, with a flashing-light prewarning time before delayed descent of the gates. Current practice is dual gate arms, one blocking travel in each direction. Their length varies depending on the width of travel lanes they are to block. They are reflectorized and have additional red lights flashing alternately to increase visibility at night. The flashing lights are activated and delayed descent of the gate arms is initiated through signals sent to wayside equipment from railroad track circuitry activated by approaching trains. Failsafe design practices requiring closed railroad circuits activate the flashing lights and automatic gates. This design practice is implemented in case of any system failure, protecting motorists from a possible train approach.

Addition of automatic gates to crossings with flashing signals or as part of a complete installation at a crossing depends on a number of factors in an engineering study, as well as on guidelines developed by states and the U.S. Department of Transportation that indicate the need for both flashing lights and gates.

A warning bell is an audible device used to supplement flashing lights and gates and is considered effective as a warning to pedestrians and bicyclists. Activation is through the same railroad track circuitry as that for lights and gates; however, the circuitry can be designed to end the ringing either after the lead end of the train has reached the crossing or near the end of gate descent.

Train detection to activate flashing lights and gates is through a railroad circuit defined as a control circuit that includes all train movement detection and logic components that are physically or electrically integrated with track structures or associated manual controls. The MUTCD requires that railroad track circuits where trains operate at speeds of 20 mph or higher provide operation of active warning devices a minimum of 20 seconds before arrival of a train. Where speeds of trains on a given track vary considerably under normal operation, special devices or railroad circuitry provides a constant or uniform warning time before train arrival at crossings. These are known as constant warning time or grade crossing predictor devices and have now become standard means for train detection in the railroad industry.

Highway traffic signals at or near grade crossings, normally within 200 feet, are required to operate in a manner to provide highway users the opportunity to clear the crossing area or be stored in a manner that avoids entrapment and optimizes their safety. Highway signal operations are preempted to provide this operation, which requires an electrical circuit between the control relay of the grade crossing warning system and the traffic controller. Both the highway circuit and railroad circuit are to be operated under the closed-circuit principle. It is suggested that studies of at-grade crossings without active traffic control devices and near signalized highway intersections be studied and that preemption of the highway signal and addition of active traffic control devices at the crossing be taken under consideration. Current issues related to the operation of interconnected highway traffic signals and railroad grade crossing signals are their design and operation as well as the requirements for storage space of vehicles.

The increasing number of light rail transit (LRT) systems that operate at grade in segments of certain corridors has led to increased train-vehicle interactions in urban environments during the last two decades. Similarly, pedestrian and LRT interactions are increasing. Current issues involve drivers' compliance with respect to active warning devices. Adjacent parallel roadways and left-turn maneuvers require enhanced driver awareness of LRT. Bidirectional train arrivals that continue activation of safety devices after the departure of the first train confuse motorists and pedestrians and lead to noncompliance.

Look to the Future

Passive Traffic Control Devices

Research findings on the meaning of Advance Warning signs to highway users suggest that the sign does not meet the objective of alerting motorists to the fact that they are approaching a grade crossing. When active yellow flashers were added and activated by a train to a slightly enlarged Advance Warning sign, recognition and speed reduction improved significantly in producing the desired effect on highway users. These findings suggest that current Advance Warning sign design and placement are not effective in producing the desired effect on highway users. Research is now under way sponsored by the National Cooperative Highway Research Program to review, analyze, and compare existing and new passive traffic control signs and markings as a system to increase safe driving behavior at railroad-highway grade crossings.

Alternative designs (Ohio buckeye shield) and retroreflective treatments to improve the effectiveness of the Railroad Crossing (crossbuck) sign have shown promise. Implementation in a few states is under way, with ongoing evaluation. These new designs and treatments focus on improving visibility under all light conditions and on highway users' comprehension of expected behavior at the crossing.

Guidelines for railroad-highway grade crossings to determine the amount of illumination to facilitate collision avoidance and minimize glare have recently been developed. These new guidelines will supplement the current practice of engineering analysis by improving type, location, and compliance verification for illumination as a safety treatment.

Installation of stop signs at all railroad-highway crossings with passive traffic control devices was recently (1998) recommended by the National Transportation Safety Board (NTSB). The intended effect of requiring drivers to stop, scan the crossing environment, and proceed is counterbalanced by concerns of compliance erosion by highway users when they encounter stop signs in highway-highway applications. Enforcement issues in the railroad-highway environment are also a concern. Existing judicious application of stop signs is expected to be unchanged for the foreseeable future.

Active Traffic Control Devices

Light-emitting diode (LED) technology implemented in the highway-highway traffic signal environment has led to development and limited implementation of LED flashing signals as replacements for incandescent railroad-highway flashing signal heads. Benefits cited are improved visibility, lower power consumption, higher reliability, and longer life. A limitation is that for some users the color spectrum within which some LEDs operate does not allow those who are color blind to discriminate sufficiently between active and inactive signal states. This drawback along with issues of appropriate LED light beam spread and focus have slowed implementation. The promise of the benefits along with continued refinement are expected to overcome these deficiencies so that widespread adoption can be attained.

Automatic gate technology improvements focus on deployment methods to prevent drivers from crossing between already lowered gate arms. Gate arms that have self-deploying extension sections are being more broadly used. The additional width of coverage effectively discourages drivers from attempting this unsafe maneuver. In addition, median barriers and median retroreflective post delineators on the approach to crossings are used to prevent vehicle intrusions into the crossing area. An old practice experiencing a rebirth is four-quadrant gate arms. Operation of the four gate arms varies; either all four are lowered at once or the exit (far) gate arms are delayed to allow vehicle clearance in the track zone. All these gate technology developments and applications are receiving healthy exploration and implementation in actual service conditions except four-quadrant gates, primarily because of the need to ensure that vehicles do not become trapped through application of advanced sensor technologies. Sensor technologies employed for vehicle detection and train detection are currently being evaluated to achieve expected gains in operational control of safety devices such as four-quadrant gates.

Along with four-quadrant gates, gate arms also serve as effective barriers in the event of an intrusion. Known generically as barrier gates, these gates are designed with restraining mechanisms built into the gate arms and roadway to form a barrier that effectively prevents intrusion into the track area at a crossing. They are similar in appearance to existing gate arms, and minimal adjustments in the existing crossing environment are required.

Similar in concept is the use of a vehicle-arresting barrier system designed to prevent intrusions into the track zone of a grade crossing. The existing flashing signal, gate arms, or both are retained. However, an additional structure is required that contains a net barrier system that is lowered when the signal from the railroad circuit is received. The structure and nets are placed on each approach and block travel in both directions when they are activated.

Four-quadrant gates, barrier gates, and vehicle-arresting barriers are in evaluation now in anticipation of their deployment to serve as deterrents against intrusion for grade crossings along designated high-speed rail corridors (currently eight in number). The level of protection provided to high-speed passenger trains by barrier gates and vehicle-arresting barrier systems may allow these systems to serve as alternatives for grade separation in high-speed rail corridors. Four-quadrant gates do not provide this level of protection; however, they show promise as an effective deterrent where driver noncompliance at dual-gate crossings is a problem.

The unique train and vehicle operations of LRT, along with the geometrics and the surrounding environment, have led to equally unique solutions to address safety concerns. Starting with video observation of driver behavior, findings have led to evaluation of new active signage for pedestrians designed to communicate their expected behavior and provide information on direction of train travel and number of trains at the grade crossing. Passive countermeasures to prevent incidents include pedestrian gates, fencing, and sidewalk geometry to encourage looking for trains. Driver compliance issues are being addressed through evaluation of additional gate arms creating four-quadrant gate installations and photoenforcement to document and cite violators at dual-gate crossings.

Sensor technology to detect vehicles and proven communications technologies have led to the development and demonstration of advanced systems designed to improve traffic flow, communications, and control in highway applications. This intelligent infrastructure evolved euphemistically to become intelligent transportation systems (ITS). ITSs for highway systems have developed through a detailed open-system-architecture process with a focus on specific applications for rural and urban highway and transit systems. In 1997, the ITS Joint Program office of the U.S. Department of Transportation designated Highway-Rail Intersections as the 30th ITS user service within the national ITS program plan.

Stakeholders in ITS User Service 30 are now developing the system architecture and standards to include high-level communications between highway and train control centers, extending unprecedented communications down to users of the system such as individual trains and highway users as they approach crossings. The standards-setting process will allow the private and public sectors to deploy nonproprietary systems and technologies to facilitate the level of control, communications, and information envisioned.

Several ITS projects related to train position and control using Global Positioning System (GPS) technology, identified as positive train control (PTC), have been demonstrated in the last few years. Full-scale operational implementation of such a system is under way in Illinois. This project will be the first to employ standards jointly developed by the railroad industry and the government to make this aspect of ITS User Service 30 a reality. PTC will provide the train position and control information necessary to serve as the backbone for the fulfillment of the ITS system architecture contained in ITS User Service 30 while also fostering the development of high-speed passenger rail and grade-crossing safety technologies.

Development and implementation of these technologies and new practices form the goal for the new millennium.