New Technologies for Improving Light-Rail Grade Crossing Safety

Linda J. Meadow, *Los Angeles County Metropolitan Transportation Authority*
James P. Curry, *Parsons Brinckerhoff/DMJM*

Light-rail transit (LRT) systems have become popular throughout the world because of their ability to operate both on and off city streets, with large capacity for transporting passengers and frequent stops in urban areas. However, operation of LRT systems in shared right-of-way presents an opportunity for collisions. Many safety problems are the result of failure of motorists and pedestrians to obey or accurately understand warning devices and traffic controls. New technologies, such as those of intelligent transportation systems (ITS), are being applied to improve safety at railroad grade crossings in Los Angeles County on the Metro Blue Line (MBL), a 22-mi (35-km) light-rail line. The Los Angeles County Metropolitan Transportation Authority (MTA) has demonstrated that photographic enforcement can assist in reducing the number of traffic accidents. For MBL grade crossings, camera equipment is activated by vehicles running under or around crossing gates or making left turns against red-turn arrows. On a 7-month demonstration project in the city of Compton, the number of violations recorded by the equipment dropped off dramatically from one violation per hour to one violation every 12 hr. In downtown Los Angeles, where motorists make left turns on red-arrow signals in front of the train, a demonstration project using photographic enforcement has resulted in a 34 percent reduction in violations. Another ITS technology being used on the MBL is the AUTOSCOPE video detection system. This system is being used to detect vehicles making illegal left turns across the MBL tracks, which triggers the photographic enforcement camera to take pictures of violators. New technologies are being incorporated for two other safety improvement projects. A four-quadrant or full-closure crossing gate system will be installed at one MBL grade crossing. A wayside horn system was tested that allows an approaching train to sound a horn at the grade crossing for motorists and pedestrians using the crossing. The horn equipment is activated by the train operator. The MTA successfully sponsored the Rail Transit Safety Act, a California-wide bill that imposes additional fines and points on persons who violate rail grade crossing safety laws. The legislation also allows a judge to order a grade crossing violator to attend traffic school and view a film on rail transit safety. In addition, it requires the Department of Motor Vehicles (DMV) to include more information on rail transit safety in its handbooks and other publications. The MTA supported the Rail Transit Safety Enforcement Act, another California-wide bill, which clarifies the use of photographic enforcement for grade crossing violations and places a DMV hold on violators who do not pay grade crossing citation fines.

Light-rail transit (LRT) systems are being developed in urban areas throughout North America, operating on newly constructed rights-of-way or on upgraded existing trackage. The introduction of LRT into medium-sized to large urban areas often results in the creation of new highway-rail grade crossings. Although some LRT systems operate partially below or above ground (such as portions of the LRT systems in Boston, Buffalo, Cleveland, Edmonton, Los Angeles, Newark, Philadelphia, Pittsburgh, St. Louis, and San Francisco), most cities adapt the lower-cost approach of placing most or all of the system on city streets, in medians, or in separate at-grade rights-of-way.

Operation of LRT in urban shared right-of-way can be attractive, but it introduces the potential for collisions between motorists, pedestrians, or bicyclists and the train. The Institute of Transportation Engineers (ITE) recently conducted a survey of 17 LRT operating systems concerning their operating practices at grade crossings. Survey responses indicated a wide range of safety-related concerns and problem areas. The most critical areas of concern identified by the survey respondents included the following:

- Motorists' disobedience of traffic laws, specifically motorists running around closed crossing gates or making illegal turns in front of the light rail vehicle (LRV) at intersections;
- Motorist confusion over traffic signals, LRT signals, and signage at intersections; and
- Pedestrian inattention or confusion at station areas and street LRT crossings.

The Transit Cooperative Research Program (TCRP) Project A–5, Integration of Light Rail into City Streets, has confirmed these problem areas and has provided additional insights into specific safety problem areas for LRT street running operations under 35 mph (56 km/hr). An additional TCRP study (Project A–13) will focus on LRT operations over 35 mph.

Each of these problems has been experienced by the Los Angeles County Metropolitan Transportation Authority (MTA) at crossings on its 22-mi (35-km) Metro Blue Line (MBL) (Figure 1). There were over 250 train-vehicle and train-pedestrian collisions in the first 4 years of MBL revenue operations, from July 1990 through April 1995. The collisions resulted in 28 fatalities and numerous injuries.

The MBL is an LRT line that runs in a subway in downtown Los Angeles for about 1 mi (1.6 km), along the middle or side of city streets for about 6 mi (9.6 km) of its length in downtown Los Angeles and downtown Long Beach, and on its own semiexclusive right-of-way for 15 mi where it operates adjacent to the Southern Pacific lines. The MTA is applying a variety of solutions in the areas of enforcement, engineering, education, and legislation to address public safety problems at MBL grade crossings. Although certain technological strategies can successfully reduce collisions, such as the use of medians to prevent cars from running around crossing gates, the MTA has embraced new technologies identified in the U.S. Department of Transportation's intelli-

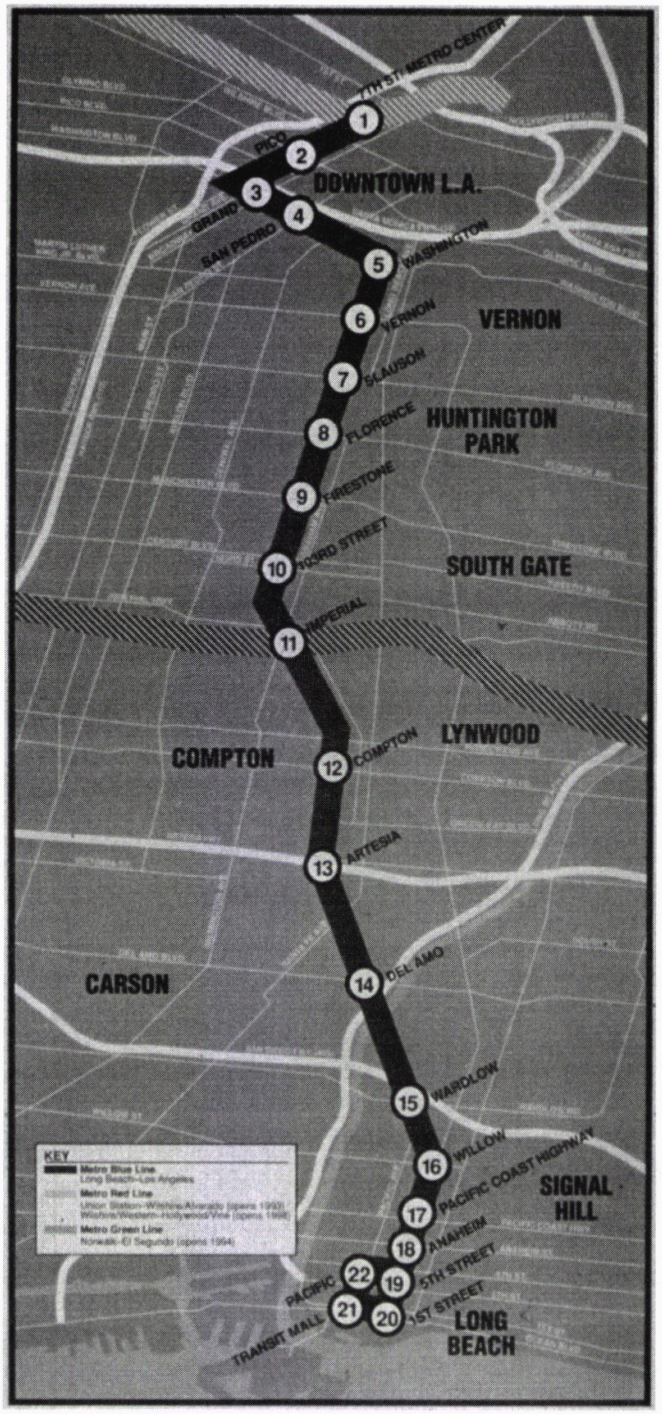

FIGURE 1 Metro Blue Line map.

gent transportation systems (ITS) program. The MTA is an active participant in the development of LRT guidelines and standards for signage, signals, and roadway markings. The Light Rail Safety Committee of the California Traffic Control Devices Committee produced the Light Rail Safety Manual, which will be referenced as part of the Caltrans Traffic Manual for use by California light-rail properties. The MTA is also working with the

National Committee on Uniform Traffic Control Devices to produce a section on LRT to be included in the 1997 revision of the *Manual on Uniform Traffic Control Devices* (MUTCD).

The Los Angeles MBL Grade Crossing Safety Program was initiated in March 1993 to evaluate various means to discourage or prevent illegal movements by vehicles at grade crossings that cause train-vehicle collisions. Although the program is focused primarily on evaluating measures to decrease train-vehicle collisions, the safety program is also concerned with improvements that will reduce train-pedestrian collisions. The MTA is seeking to apply innovative equipment and methods developed for street and highway traffic applications. These engineering improvements will address unique characteristics of MBL grade crossings and improve public safety.

The safety program includes four elements:

- Enforcement of traffic regulations at grade crossings using police officers and automated photographic enforcement systems;
- Engineering improvements, including the use of ITS technologies, warning devices, and street and traffic signal improvements;
- Legislation to establish higher fines and statewide rail safety educational programs; and
- Bilingual public information and safety education.

Vehicular and Pedestrian Hazard Analysis for Light-Rail Grade Crossings

As part of the MBL Grade Crossing Safety Improvement Program, the MTA performed a hazard analysis for various types of light-rail grade crossings. The analysis consisted of two parts:

- Identification of factors or conditions contributing to train-vehicle and train-pedestrian accidents, and
- Mitigating traffic control devices and systems.

After the grade crossing hazard analysis results had been developed, MBL grade crossings were analyzed to determine which traffic control devices and systems could be applied to mitigate the factors and conditions contributing to accidents at each of the crossings. Then a plan was prepared to implement the selected solutions.

Public Perception of Grade Crossing Problem Areas

An important component of the design of a safety improvement program is to determine community attitudes concerning safety problems and possible areas for improvement along the rail line. The MTA performed a bilingual (English and Spanish) survey of 400 persons who live near the MBL and use MBL grade crossings at least once a week. Residents were asked to describe problem areas that affect safety at grade crossings; the following problems were identified:

- Lack of understanding by drivers and pedestrians that MBL trains reach the intersection quickly after the warning lights start flashing (80 percent),
- Attempts by drivers to beat the train by driving around lowered crossing gates (76 percent),
- Length and slowness of Southern Pacific's freight trains (70 percent),
- Lack of understanding by drivers and pedestrians that two, and sometimes three, trains can go through an intersection at the same time (70 percent), and
- Lack of enough barriers to keep pedestrians and children off the tracks (68 percent).

New Technologies for Grade Crossing Safety

New technologies that can be applied to solve safety problems at highway-rail grade crossings were identified as a part of the ITS program by the Texas Transportation Institute (TTI). Additional information may be provided to the train operator, central dispatching facility, motorists, and pedestrians so informed decisions can be made to avoid an accident. New technologies may be applied for safety-related problems in the areas of intrusion detection, collision avoidance, dynamic displays, vehicle proximity alerting, automated wayside horns, and warning signs.

The MTA is applying ITS technologies to implement elements of the Grade Crossing Safety Improvement Program, including projects for the installation and operation of photographic enforcement systems, the trial installation of a four-quadrant crossing gate system, the use of dynamic displays, and automated wayside horns. Three of these projects are described in the following sections of this paper.

In addition, the MBL Grade Crossing Safety Improvement Program includes the following projects:

- Installation of swing gates at pedestrian-only crossings at the Artesia and Imperial stations;
- Installation of a railroad-style pedestrian gate at the Florence Avenue, Gage Avenue, and Vernon Avenue crossings;
- Construction of center line medians at six crossings (generally, it is not possible to construct medians at MBL crossings because of streets running parallel to the tracks);

• Testing of active No Left Turn and Train signs in conjunction with the relocation of the train T-signals;
• Testing of programmed visibility signal heads for the through and left-turn signals at selected intersections on Long Beach Boulevard where left turns are made across the MBL tracks;
• Left-turn lanes and separate left-turn phases at five signalized intersections where left turns are made across the MBL tracks;
• Evaluation of Second Train warning signs, including the investigation of alternative methods for activating signs that provide directional, arrival time, or second-train warnings; and
• Investigation of in-vehicle alerting systems for vehicles hauling hazardous materials and school transportation vehicles.

Photographic Enforcement

One major thrust of the improvement program has been expanded grade crossing enforcement efforts, which have included the use of both Sheriff's deputies and photographic enforcement systems. In particular, the MTA's use of photographic enforcement equipment at MBL crossings has generated an impressive reduction in the number of crossing violations. With the efforts being made to reduce the number of violations at crossings, it is expected that the number of collisions will also be reduced.

The MTA has completed five demonstration projects of photographic enforcement equipment at grade crossings. On the basis of the demonstration project results, the MTA is currently proceeding with the installation of photographic enforcement equipment at 17 crossings on the cab signal route segment. The selection of U.S. Public Technologies for the installation and operation of the equipment was approved by the MTA Board of Directors on February 22, 1995. It is expected that the equipment will be in place and operational at 3 crossings by July 1995 and at 10 crossings by early 1996.

System Description

Photographic enforcement systems use high-resolution cameras to photograph motorists driving under or around railroad crossing gates. Bilingual signs informing motorists that photographic citations are being issued at the crossing are installed on all street approaches to the crossing (Figure 2*a*). The camera equipment is mounted in a 2-ft (3.7-m) high bullet-resistant cabinet (Figure 2*b*). The camera is triggered when vehicles cross inductive loop detectors in the ground after the gates have started down or are already lowered. Two photographs of the vehicle, its license plate, and the driver's face are taken as the basis for issuing a citation as required by the California Vehicle Code. Superimposed on each photograph is the date and time of the violation, the speed of the violating vehicle, and the number of elapsed seconds since the red flashing lights were activated at the crossing (Figure 2*c*).

Photographic enforcement systems have been used worldwide, including in several cities in the United States and Canada, to capture speed and red-light violations. Photoradar equipment has been widely used for the enforcement of speed violations. In addition to freeing police officers from traffic enforcement work, the use of photographic enforcement for speed and red-light violations has significantly reduced collisions wherever it has been used.

Demonstration Project Results

Two demonstration projects were carried out at gated crossings. A 7-month demonstration project at Compton Boulevard was completed in September 1993. The project resulted in a 92 percent reduction in the number of violations occurring at the crossing, reaching one violation every 12 hr.

A 3-month demonstration project was completed at Alondra Boulevard in September 1993. Signs and the camera pole and cabinet were installed for about 6 months at this location before citations were issued. Grade crossing violations dropped by 78 percent from 0.50 violation per hour in December 1992 to 0.11 violation per hour in September 1993 when the demonstration project was completed. A total of 265 citations were issued for violations recorded by the camera equipment at these crossings.

Photographic enforcement equipment was operational at the intersection of Washington Boulevard and Los Angeles Street for about 7 months from September 1993 through the middle of April 1994. The equipment was installed to record left turns made across the MBL tracks against a red left-turn arrow (toward downtown Los Angeles). For about 6 weeks from February 15 through March 31, 510 citations were issued to violators recorded at the intersection.

The rate of left-turn violations on weekdays declined by approximately 34 percent over the duration of the demonstration project, dropping from 2.02 per hour on the average during September and October to approximately 1.34 per hour for the month of March. This is a much lower percentage reduction than experienced for crossing violations at Compton and Alondra boulevards.

The other two demonstration projects have involved testing alternative camera system and vehicle detection technologies. The first project, completed in April 1994, used a low-resolution digital camera system to record left-turn violations. Images of the recorded violations

(a) (b) (c)

FIGURE 2 Photographic enforcement (*a*) sign, (*b*) pole, and (*c*) citation photograph.

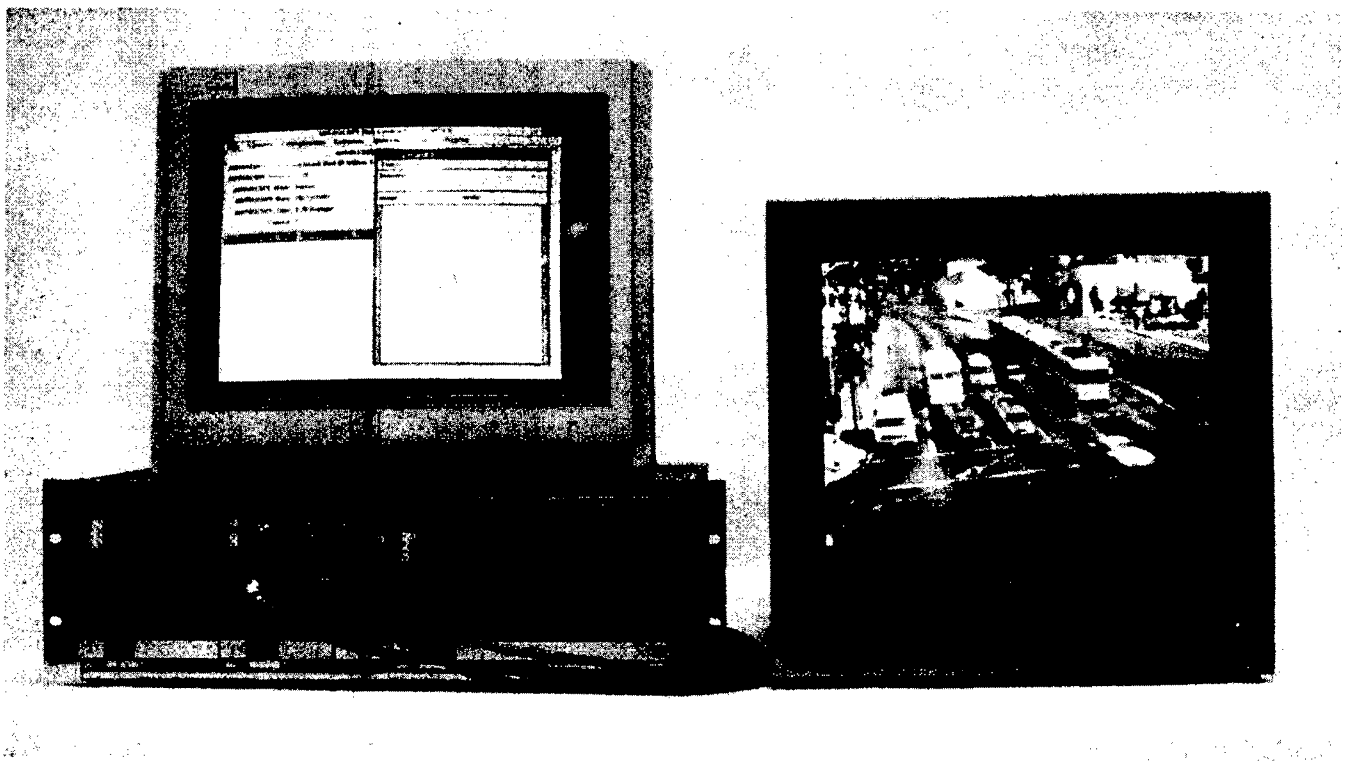

FIGURE 3 AUTOSCOPE screen showing intersection at Long Beach Boulevard and Willow Street.

were stored and transmitted by a cellular telephone link at night, eliminating the need to change and develop film.

The second project under way in the city of Long Beach involves video loops using the AUTOSCOPE system to detect motorists making illegal left turns across the MBL tracks. The AUTOSCOPE system can detect traffic at numerous locations within the field of view of the camera. The user specifies the locations using a mouse and interactive software. Detection zones can be placed along the tracks or on the street. When a vehicle or train passes through a detection zone, a detection signal is generated, the same type of signal that would be generated by an inductive loop or other vehicle detection device installed in the street. A view of the equipment showing the intersection in Long Beach where the AUTOSCOPE image and vehicle detectors are operational is shown in Figure 3.

Setting up the detection loops at this location has involved eliminating false camera triggers caused by the following conditions:

- Shadows of the train (into the left-turn lane);
- Eastbound pedestrian and high vehicle traffic on Willow Street;
- Southbound high vehicle traffic in the lane next to the left lane on Long Beach Boulevard; and
- Differences in the system response time for dark and light vehicles.

Recent Accident Experience

Recent accident statistics suggest that the MTA's enforcement efforts are having the desired results. On the cab signal route segment where trains operate at high speeds, there were two train-vehicle accidents at a gated crossing in 11 months. For each of the prior 3 years of MBL operation, there were seven train-vehicle accidents at gated crossings.

Systemwide Installation

The installation and operation of photographic enforcement equipment during the five demonstration projects have indicated some areas in which special attention was required during the demonstration projects and further attention will be necessary in order to make the system operational at 17 MBL crossings:

- Placement of the camera equipment at crossings, taking into account the width of the crossing area, ambient lighting conditions, and the location of traffic signals and crossing protection equipment;
- Placement of the detector loops, especially for left

turns and at crossings where loops are already in place for traffic signals;

- Working out citation processing details with the participating courts, Department of Motor Vehicles, and City or District Attorney's office;
- Development of a working relationship with the law enforcement agency that has jurisdiction for the crossings;
- Defining a crossing violation consistent with applicable sections of the California Vehicle Code for grade crossing and left-turn violations;
- Obtaining clarification concerning the use of photographic enforcement equipment at grade crossings through discussions with court officials and legislative initiatives, such as the Rail Transit Safety Enforcement Act and Senate Bill 1802, currently California law.

As already noted, it is expected that the photographic enforcement equipment will be in place and operational at 3 crossings by July 1995 and at 10 crossings by early 1996.

The U.S. Department of Transportation is funding the preparation of a report concerning the effectiveness of photographic enforcement and the lessons learned from its implementation at MBL grade crossings. Funding participants include the Federal Railroad Administration, the Federal Highway Administration, and the Federal Transit Administration. It is expected that this report will be available by as early as mid-1996.

Public Perception of Enforcement

Community survey results indicated that 83 percent of those living near the MBL who use MBL crossings at least once a week support the use of automated photographic enforcement equipment for the enforcement of traffic laws at grade crossings. Seventy-one percent of the survey respondents believed that use of the photographic enforcement equipment would reduce the number of accidents.

Four-Quadrant Crossing Gate System

A highway-rail grade crossing may be considered to have four quadrants formed by the rail tracks running from left to right and the street or highway crossing the tracks running from top to bottom. With a four-quadrant gate system, gates at both entrances to and exits from the crossing completely closed off the crossing when trains approach (the typical crossing gate configuration).

The use of this type of crossing gate system offers an approach for eliminating or minimizing grade crossing accidents without the high costs and impacts of grade separation. For the MBL, it offers the potential for eliminating collisions involving motorists making left turns from streets running parallel to the tracks. This system can also potentially decrease the number of collisions involving motorists driving around closed crossing gates from the crossing street who are hit by a second train as it passes through the crossing.

A number of design-related factors typical of many MBL grade crossings make it appropriate to consider the use of four-quadrant gates at these crossings. In addition, the cost of installing and maintaining four-quadrant crossing gate systems is substantially less than the costs of grade separation.

The first design-related factor is that grade crossings from 24th to 103rd streets and at Manville Street on the cab signal route segment require vehicles to cross four tracks. Crossings at 20th Street and from 108th Street to Greenleaf Boulevard on the cab signal segment require vehicles to cross three tracks. The width of these crossings makes it easier for vehicles to drive around lowered gates, using an S-shaped path.

Second, vehicles are able to make left turns from streets running parallel to the tracks at many MBL grade crossings. These turns can be made easily around lowered crossing gates when drivers try to avoid being delayed by a train.

Third, many of the accidents on the cab signal route segment have involved a vehicle driving around lowered gates to avoid waiting for a slow-moving SP freight train or after a train passes through the crossing. The vehicle is then hit by another train that was not seen by the driver. Typically in this situation, the crossing gates are down for a longer time than usual (or the driver, seeing a slow freight train approaching, anticipates that the gates will be down for a longer time).

The MTA is installing a four-quadrant crossing gate system at the 124th Street crossing in the Willowbrook area. At this crossing, one SP track runs parallel to the MBL tracks and streets also run parallel to the tracks on both sides.

Trial Installation Project Objectives

The objectives of the demonstration project are as follows:

- Design and install a four-quadrant gate system that eliminates the risk that motorists will be trapped between closed entrance and exit crossing gates;
- Investigate the use of ITS technologies, which are becoming more widely used for a variety of street and highway traffic improvement applications, to improve highway-railroad grade crossing safety;
- Evaluate the effectiveness of a four-quadrant gate system in preventing accidents caused by drivers going

around closed crossing gates in an urban LRT operating environment; and

- Determine the additional costs of constructing and maintaining a four-quadrant gate system.

Existing North American Four-Quadrant Gate Installations

Four-quadrant gate systems are currently operational in the United States and Canada at three locations:

- Broad Street in Red Bank, New Jersey, as part of New Jersey Transit;
- 24th Street in Cheyenne, Wyoming, as part of the Burlington Northern; and
- 20th Avenue in Calgary, Alberta, as part of Calgary Transit.

Planned installations include

- Gilette, Wyoming, on the Burlington Northern;
- Charlotte, North Carolina, on the Norfolk Southern;
- Mystic, Connecticut, on the Northeast Corridor high-speed rail line; and
- Proposed high-speed rail corridors that are authorized by ISTEA (Section 1010), for example, 7 out of 73 crossings on the 67-mi (107-km) Miami–West Palm Beach corridor identified by the Florida Department of Transportation.

Design Approach and Assumptions

Four safety features, involving different approaches for preventing vehicles from being trapped between the lowered entrance and exit gates, have been considered as elements of the design for the four-quadrant crossing gate system.

Delayed Lowering of Exit Gates The exit gates will be lowered a number of seconds after the entrance gates are down (or have started down). The exit gates at the Broad Street, New Jersey, crossing where four-quadrant gates are used are delayed by 8 to 10 sec after the entrance gates are lowered. At the 24th Street crossing in Cheyenne, Wyoming, the exit gates are delayed 2 to 4 sec after the entrance gates are lowered. In proposed guidelines issued in November 1992, the Federal Railroad Administration has suggested that exit gates should start to descend from 1 to 3 sec after the entrance gates, providing only a short delay time in the lowering of the exit gates.

Vehicle Detection System A vehicle detection system using inductive loops will be interfaced with the exit gate control circuits so that the exit gates are not lowered when a vehicle is detected in the track area.

Fail-Safe System for Exit Gates The exit gates will be counterbalanced so that they fail safe in the up position. The gates will need to be driven down and then held down.

Video Surveillance FTA is providing funding for the installation of video surveillance equipment at the 124th Street crossing. AUTOSCOPE will be used to provide video surveillance and backup loop detection.

Wayside Horn System

MBL train operators are required to sound the train horn when approaching grade crossings. For grade crossings on the cab signal route segment, the horns are sounded 6 to 8 sec before trains enter the crossings.

In accordance with California Public Utilities Commission General Order 143-A, train horns are required to provide an audible warning of at least 85 dBA for a distance of 18 ft (30.48 m) from the train. Although intended to warn motorists and pedestrians at grade crossings, the train horns can be loud and disruptive for persons living and working adjacent to the MBL tracks. For the MBL as well as other rail projects in Southern California, wayside horns may provide an effective means of mitigating certain noise impacts resulting from train operations.

An MBL wayside horn demonstration project was conducted. The train horn was mounted on a pole at a crossing on the MBL and at two crossings on the Pasadena extension to the MBL (under final design). The train operator actuated the horn by hitting a button mechanism attached to the horn. At the MBL crossing of Stockwell Street and Willowbrook Avenue, a focus group of 25 people was recruited from households and businesses within 1 mi of the grade crossing.

Four focus groups were set up around the intersection: two at opposite sides of the crossing, the third approximately 55 ft (90 m) down the parallel street, and the fourth approximately 55 ft down the cross street. The focus groups were asked to evaluate the horn on the train and the wayside horn at several different decibel levels.

The survey was designed to determine the focus group's opinions on the effectiveness of the wayside horn versus the train horn for warning motorists and pedestrians. Over 50 percent of the focus group respondents believed that the wayside horn was more effective than the train horn.

The use of radar detection is being explored for wayside horn annunciation. Using this approach, train speed will be determined by radar. Then the wayside horn will be activated automatically without operator involvement. The way to alert the train operator that the horn has sounded needs to be investigated as part of this demonstration project.

Legislation

In the last 2 years, the MTA has successfully sponsored and supported the Rail Transit Safety Act and the Rail Transit Safety Enforcement Act. The Rail Transit Safety Act, which became law in California on January 1, 1995, seeks to decrease the number of rail-related accidents by imposing additional fines and points on those who violate rail grade crossing safety laws. The legislation provides county transportation authorities, local governments, and law enforcement agencies with the tools needed to implement expanded enforcement and public education efforts targeted at rail grade crossing safety.

Specifically, the Rail Transit Safety Act provides for the following:

1. An additional fine for grade crossing violations: Currently, depending upon the jurisdiction, the fine for not stopping at a grade crossing when the warning signals are flashing or for driving around a closed gate is $104, whereas the fine for a high-occupancy-vehicle (HOV) lane violation, where the violation does not threaten the life of the driver or of others, is $271. The Rail Transit Safety Act authorizes the court to levy an additional $100 fine for a first violation of a rail grade crossing safety law. If a person is convicted of a second or subsequent offense, the court may order an additional fine of $200.
2. Traffic school for grade crossing violations: A person convicted of a grade crossing violation may be ordered to attend traffic school and view a film on rail transit safety.
3. Required section in Department of Motor Vehicles (DMV) driver handbooks: DMV driver handbooks are required to include a section on rail transit grade crossing safety.

The Rail Transit Safety Enforcement Act clarifies the use of photographic enforcement at highway-railroad grade crossings. It also allows the court to place a hold on violators who try to reregister their vehicle or renew their license without paying the fine for violation of grade crossing laws.

Further legislation is needed to allow transit agencies to recover portions of the fine revenues from grade crossing violations. Thus funding will be available for safety measures to be continued, such as photographic enforcement.

Conclusion

LRT safety issues can be addressed by using new technologies. Methods being evaluated include enforcement, engineering improvements, and legislation. Many of the techniques are proving to be successful in achieving safety objectives.

The MTA has successfully shown that photographic enforcement, which uses 35-mm complex camera units combined with inductive loops and custom software, reduces light-rail crossing violations and accidents. In addition, the MTA is conducting demonstrations of four-quadrant gates and wayside horns. The use of four-quadrant crossing gates offers an approach for eliminating or minimizing grade crossing collisions without the high costs and impacts of grade separation. Specifically for the MBL, it offers the potential for eliminating collisions involving motorists making left turns from streets running parallel to the tracks.

The MTA successfully sponsored the Rail Transit Safety Act and the Rail Transit Safety Enforcement Act, both of which are California-wide bills. The former imposes additional fines and points on those who violate rail grade crossing safety laws, allows a judge to order a grade crossing violator to attend traffic school and view a film on rail transit safety, and requires the DMV to include more information on rail transit safety in its handbooks and other publications. The latter clarifies the use of photographic enforcement at highway-railroad grade crossings. It also allows the court to place a hold on violators who try to reregister their vehicle or renew their license without paying the fine for violation of grade crossing laws.

Enforcement, engineering improvements, and legislation have proven to be a successful combination in reducing collisions on light-rail lines.