PB2003-104591

U.S. Department
of Transportation
Federal Transit
Administration

Use of Left Turn Gates at Highway Railroad Grade Crossings on the Los Angeles Metro Blue Line

December 31, 2002

Prepared by
PB Farradyne
Division of Parsons Brinckerhoff Quade & Douglas, Inc.
444 South Flower Street, Suite 3700
Los Angeles, CA 90071

Prepared for
Los Angeles County Metropolitan Transportation Authority
One Gateway Plaza
Los Angeles, CA 90012

Sponsored by
Federal Transit Administration
Office of Research, Demonstration & Innovation
U.S. Department of Transportation
Washington, DC 20590
Email: *[research@fta.dot.gov]*
Fax: *202.366.3765*

Report Number
FTA-CA-26-7010-02

REPORT DOCUMENTATION FORM	Form Approved OMB No. 0704-0188

Public reporting burden for this collection of information is estimated to average 1 hours per response, including the time for reviewing the instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing this burden, to Washington Headquarters Services, Directorate for Information Operations and Management and Budget, Paperwork Reduction Project (0704-0188), Washington, DC 20503

1. AGENCY USE ONLY (Leave Blank)	2. REPORT DATE December 31, 2002	3. REPORT TYPE AND DATES COVERED Final Report

4. TITLE AND SUBTITLE
Use of Left Turn Gates at Highway Railroad Grade Crossings on the Los Angeles Metro Blue Line

5. FUNDING NUMBERS

6. AUTHOR(S)

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS (ES)
PB Farradyne, Division of Parsons Brinckerhoff Quade & Douglas, Inc. (*)
444 South Flower Street, Suite 3700
Los Angeles, CA 90071

8. PERFORMING ORGANIZATION REPORT NUMBER

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS (ES)
U.S. Department of Transportation
Federal Transit Administration
Office of Research, Demonstration, and Innovation
400 Seventh Street SW, Room. 9401
Washington, DC 20590

10. SPONSORING/MONITORING AGENCY REPORT NUMBER
FTA-CA-26-7010-012

11. SUPPLEMENTARY NOTES: (*) Under contract with Los Angeles County Metropolitan Transportation Authority. LACMTA Director of Rail Operations Safety, Vijay Khawani (213) 922-3185 directed this project.

12a. DISTRIBUTION/AVAILABILITY STATEMENT
Order from: National Technical Information Service, Springfield, VA, 22161, 703.606.6000, or FTA Website [www.fta.dot.gov]

12b. DISTRIBUTION CODE

13. ABSTRACT (Maximum 200 words)
Accident records for Los Angeles Metro Blue Line indicate that a large number of train/vehicle collisions take place at grade crossings where there are streets running parallel to LRT tracks and motorists are permitted to make left turns across the tracks. One approach to reducing train/vehicle accidents at these locations is to prevent motorists making left turns from entering the track area in front of approaching trains. This could be accomplished by the use of a left turn gate that blocks motorists from exiting the left turn lane or entering the grade crossing as a train approaches. A number of left turn gate configurations and types were reviewed and, from the review, the use of full closure crossing gates provided a number of advantages over other configurations provided that the potential hazard of trapping motorists in the track area behind the lowered crossing gates could be effectively mitigated. An experimental full closure or four quadrant crossing gate system, designed to deter motorists from making left turns around lowered railroad crossing gates, was installed at the 124th Street intersection in south central Los Angeles. During the experimental phase, over 41,000 Metro Blue Line light rail trains and Union Pacific Railroad freight trains passed through the intersection at speeds up to 55 miles per hour. Data recorded for the first six months of operation at the 124th Street intersection shows that the approach is working to prevent motorists from driving around the lowered crossing gates. With the system in place, there has been an impressive 94 percent reduction in the number of risky moves by motorists using the intersection. The use of full closure crossing gates at the 124th Street intersection is supplemented with a trapped vehicle detection system. A series of inductive loop detectors, similar to those widely employed throughout North America for traffic signal control applications but incorporating a unique design that provides for the verification of the track area loop detectors each time that a train approaches the crossing, were installed in the track area and used to mitigate trapping vehicles between the lowered gates.

14. SUBJECT TERMS
grade crossings, railroad, light rail transit, safety, highway railroad intersections, four quadrant gates, railroad crossing gates, vehicle detection

15. NUMBER OF PAGES
N/A

16. PRICE CODE

17. SECURITY CLASSIFICATION OF REPORT	18. SECURITY CLASSIFICATION OF THIS PAGE	19. SECURITY CLASSIFICATION OF ABSTRACT	20. LIMITATION OF ABSTRACT
Unclassified	**Unclassified**	**Unclassified**	

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LIST OF ABBREVIATIONS AND ACRONYMS

AAR	American Association of Railroads
AC	Alternating Current
Amps	Amperes
CCTV	Closed Circuit Television
Caltrans	State of California Department of Transportation
CPUC	State of California Public Utilities Commission
EMC	Engineering Management Consultant
FRA	Federal Railroad Administration
FTA	Federal Transit Administration
HRI	Highway Rail Intersection
ITE	Institute of Transportation Engineers
LACDPW	Los Angeles County Department of Public Works
LACMTA	Los Angeles County Metropolitan Transportation Authority
LADOT	Los Angeles Department of Transportation
LRT	Light Rail Transit
MBL	Metro Blue Line
MIN	Minimum
NB	Northbound
NEMA	National Electronics Manufacturers' Association
OS-9	Computer operating system used for real-time data processing applications
PBF	PB Farradyne
PC	Personal computer
SB	Southbound
TWC	Train-to-Wayside Communications
UPRR	Union Pacific Railroad
VAC	Alternating Current Voltage
VCR	Video Cassette Recorder
VDC	Direct Current Voltage
VMEbus	Computer architecture based on IEEE-1014-1987. VME stands for VERSAmodule Eurocard.
XR	Crossing Relay
XPR	Crossing Relay Repeater

1. SUMMARY

Accident records for Metro Blue Line Light Rail Transit (LRT) line indicate that a large number of train/vehicle collisions take place at grade crossings where there are streets running parallel to LRT tracks and motorists are permitted to make left turns across the tracks. One approach to reducing train/vehicle accidents at these locations is to prevent motorists making left turns from entering the track area in front of approaching trains. This could be accomplished by the use of a left turn gate that blocks motorists from exiting the left turn lane or entering the grade crossing as a train approaches.

An experimental full closure or four quadrant crossing gate system, designed to deter motorists from driving around lowered railroad crossing gates at a highway-rail intersection on the Long Beach Blue Line, was installed at the 124th Street intersection in south central Los Angeles in October, 1998. The experimental system has been in continuous operation since that date. Nearly 400,000 Long Beach Blue Line light rail trains and Union Pacific Railroad freight trains have passed through the intersection at speeds up to 55 miles per hour.

Figure 1-1
FOUR QUADRANT GATES DOWN FOR NORTHBOUND METRO BLUE LINE TRAIN AT 124TH STREET

Figure 1-2
FOUR QUADRANT GATES DOWN FOR UPRR FREIGHT TRAIN

Envisioned by the Los Angeles County Metropolitan Transportation Agency (LACMTA) in 1993 as a means to reduce the number of collisions at highway-rail intersections on the Long Beach-to-Los Angeles Metro Blue Line and adjacent Union Pacific Railroad Wilmington Branch that serves the Port of Los Angeles, the LACMTA obtained authorization for the trial installation of full closure crossing gates from the California Public Utilities Commission (CPUC) in September, 1995. The trial installation was placed into service at the 124th Street crossing in October, 1998 by the LACMTA.

Full closure crossing gates involves the installation of additional railroad crossing gates, that when lowered together with the conventional crossing gates, serve to completely block motorists from entering the intersection. In order to make sure that motorists are not trapped on the tracks when the crossing gates are lowered, the overall system incorporates a unique track area highway vehicle detection system, employing the latest generation of traffic signal control systems technology, that causes the additional crossing gates to be held in the up position, when a motorist is detected in the track area, until that motorist has exited safely from the track area.

The exit gates are controlled by Safetran S-20 gate mechanisms, modified so that the gates are driven down and held down and so that the gates will fail safe by counterweighting in the up position. The operation of the exit gates is controlled by relay logic using standard railroad circuits. The exit gates will be prevented from lowering if a vehicle is detected in the track area. The exit gates will be held up, or if already started down, be returned to the up position, by interrupting the circuit which provides the gate down control signal to the exit gate mechanisms.

The full closure crossing gate system at 124th Street is the first of its kind in North America at a highway-rail intersection with LRT trains. It is also the first system in North America where the trapped highway vehicle detection system has been employed in unattended operation to hold the exit gates up so that motorists can exit safely from the track area.

1.1 Operating Results From 124th Street

Continuous video and event recorder data for over 41,000 gates down calls by LRT and UPRR freight trains from October, 1998 through April, 1999 was collected and tabulated to evaluate motorist behavior and system performance at the intersection. During this time, there was no instance observed where a vehicle was not detected in the track area so that the exit gates were held up, or returned to their up position after starting down, to allow a motorist to exit safey from the track area. During this time, the exit gates were held up, or returned to their vertical position, 1,119 times, about one time every 36 gate down calls on the average. Interestingly, the exit gates were held up more often for motorists when UPRR freight trains were approaching the crossing; about one time every 22 gate down calls for freight trains in comparison with one time every 39 gate down calls for LRT trains.

Most importantly, data recorded for the first six months of operation at the 124th Street intersection showed that the approach was working to prevent motorists from driving around the lowered crossing gates.

Data collected before the system was installed showed that motorists drove around the lowered gates, taking the risk of being hit by train, about three times every five days on the average. Since the installation of the additional crossing gates, motorists have driven around the lowered gates, under one of the additional crossing gates or exit gates as it is being lowered, a total of seven times and, after the additional crossing gates are already down, no times. With the system in place, motorists have been observed driving around the lowered gates about once every 26 days on the average or an impressive 94 percent reduction in the number of risky moves by motorists using the intersection.

1.2 Trapped Highway Vehicle Detection System

The use of full closure crossing gates at the 124th Street intersection would not be possible without the trapped vehicle detection system. In order to lower the additional crossing gates as quickly as possible, it is necessary that vehicles in the track area be detected and, as a result of being detected, be allowed to exit safely from the track area.

The trapped vehicle detection system has been implemented on an Open Architecture VMEbus-Based Advanced Transportation Controller that meets the Caltrans 2070 Specification. The system is based on the use of "off the shelf" traffic signal control equipment. This hardware and the OS-9 operating system platform is capable of running intersection traffic control and the track area highway vehicle detection software simultaneously, although this is not being done for the trial installation at 124th Street.

A series of inductive loop detectors, similar to those widely employed throughout North America for traffic signal control applications but incorporating a unique design that provides for the verification of the track area loop detectors each time that a train approaches the crossing, are installed in the track area and used to detect vehicle presence.

Figure 1-3
TRACK AREA VEHICLE DETECTION LOOPS BETWEEN METRO BLUE LINE TRACKS

There is a clearly defined interface, both logically and electrically, between the track area vehicle detection system and the railroad circuits and related equipment that control the operation of the crossing gates. For on-going operations, the interface allows system maintenance responsibilities for both the traffic and railroad equipment to be clearly delineated.

2. INTRODUCTION

Accident records for Los Angeles' Metro Blue Line (MBL) indicate that a large number of train/ vehicle collisions take place at grade crossings where there are streets running parallel to light rail transit tracks and motorists are permitted to make left turns across the tracks. Where the crossings are controlled by traffic signals only, the MBL has experienced numerous train/vehicle collisions. At crossings equipped with railroad flashing lights and crossing gates, only the flashing sidelights aimed at the left turn lane are useful in alerting motorists making left turns across the tracks that a train is approaching.

When this project was started, there were a few examples of railroad crossing gates being used as left turn gates at highway railroad intersections. Calgary Transit had installed railroad crossing gates on the left turn lanes at two grade crossings where there are heavy left turn traffic volumes. Full closure or four quadrant gates, a variation of left turn gates, were operational at three crossings in the United States and were being considered or were under design for crossings in Connecticut, North Carolina, California, and Florida.

This project was carried out by the Los Angeles County Metropolitan Transportation Authority (LACMTA) to investigate the application of full closure crossing gates as well as other types of gates and "pop up" barriers, for locations where there is not adequate space to install gates for left turns made from streets running parallel to the tracks at grade crossings. The project was carried out using local funding and Federal Transit Administration (FTA) assistance under FTA Grant CA-26-7010

The project objectives were as follows.

- To investigate the use of railroad crossing gates or similar barriers installed to stop traffic from making left turns across light rail transit tracks when trains are approaching from streets running parallel to the tracks.
- To evaluate the use of supplemental railroad crossing gates, installed in a full closure or four quadrant gate configuration, to stop traffic from making left turns across light rail tracks at the MBL 124th Street crossing.
- To evaluate the use of a video-imaging vehicle intrusion detection system, as a non-intrusive alternative to the use of inductive loops, in conjunction with full closure crossing gates at a highway-railroad grade crossing.

This project was conducted by the LACMTA with the cooperation of the Union Pacific Railroad (UPRR) and the Los Angeles County Department of Public Works. PB Farradyne (PBF), a Division of Parsons Brinckerhoff Quade & Douglas, Inc. served as the LACMTA's Project Engineer, responsible for project design and development.

3.0 LEFT TURN GATES AT GRADE CROSSINGS

MBL accident records indicate that a large number of train/vehicle collisions take place at highway-railroad grade crossings where there are streets running parallel to light rail transit tracks and where motorists are permitted to make left turns across the tracks. This occurs at crossings on street running route segments where the crossings are controlled by traffic signals, and also at crossings on the cab signal route segment where the trains operate at high speeds and the crossings are equipped with railroad crossing gates, flashing lights, and bells. Figure 3-1 shows the view from the left turn lane on a street running parallel to LRT tracks at an intersection controlled by traffic signals.

At crossings equipped with railroad flashing lights and crossing gates, flashing sidelights aimed at left turn traffic alert motorists making left turns across the tracks that a train is approaching. In addition, at certain locations such as at the intersection shown in Figure 3-1, left red arrow indications and separate left turn phases have been implemented for traffic making left turns across the tracks. Figure 3-2 shows a crossing on the Metro Blue Line where both flashing sidelights and red left turn arrows are displayed for traffic making left turns. Figure 3-3 illustrates the use of a train-activated "TRAIN" sign in conjunction with a separate left turn phase at a signalized intersection on Santa Clara County's LRT system.

These warning devices discourage but do not prevent motorists from making left turns across the tracks when a train is approaching. A left turn gate, either a standard railroad crossing gate or other appropriate device, that prevents motorists from exiting the left turn lane as a train approaches, could be very effective in preventing this type of train/vehicle collision.

A standard railroad crossing gate can be configured in three different ways to block left turn motorists from entering a grade crossing. Two of the configurations utilize the standard railroad crossing gate as a left turn gate, one with the gate installed at 90 degrees to the left turn lane and the second with the gate turned so that it is parallel to the tracks and the left turn lane. In the third configuration, the standard railroad crossing gates serve to completely close off the crossing and are installed as exit gates in a full closure or four quadrant crossing gates system. "Pop up" traffic delineators might also be used to block motorists from making left turns at a grade crossing.

The following four possible left turn barrier configurations, three utilizing standard railroad crossing gate and one employing "pop up" traffic delineators, are discussed further in the following sections of this chapter.

- Standard railroad crossing gate, with a 12 to 15 foot gate arm for a single left turn lane, installed so that the gate arm extends across the left turn lane when lowered as a train approaches.

- Standard railroad crossing gate, with a 15 foot or longer gate arm, installed in the same location as for the first configuration except that the gate arm, when lowered, is parallel to the tracks and the left turn lane. In this case, the gate arm extends across the right-hand traffic lane exiting from the crossing track area when lowered for an approaching train.

Figure 3-1
SEPARATE TRAFFIC LANE AND SIGNAL PHASE FOR TRAFFIC TURNING LEFT FROM STREET RUNNING PARALLEL TO LRT TRACKS

Figure 3-2
RAILROAD FLASHING LIGHTS AND RED LEFT TURN ARROW FOR TRAFFIC TURNING LEFT FROM STREET RUNNING PARALLEL TO LRT TRACKS

- Standard railroad crossing gate, with a 15 foot or longer gate arm, installed so that it extends completely across the right-hand traffic lanes exiting from the crossing track area when lowered for an approaching train. This configuration constitutes a four quadrant or full closure crossing gate configuration.

- "Pop up" traffic delineators, such as the ones being used by Caltrans at certain locations to block access to freeway on-ramps and freeway traffic lanes for selected time periods, installed so that the delineators are raised to block the left turn lane when activated by an approaching train.

Figure 3-3
TRAIN-ACTIVATED WARNING SIGN FOR TRAFFIC TURNING LEFT FROM STREET RUNNING PARALLEL TO LRT TRACKS

3.1 CONFIGURATION 1: LEFT TURN GATE AT 90 DEGREES TO LEFT TURN LANE

The first configuration consists of a standard railroad crossing gate, typically 12 to 15 feet long for one left turn lane, that, when lowered, extends across the dedicated or separate left turn lane of a one-way street running parallel to the tracks. The gate acts as a barrier to prevent motorists from exiting the left turn lane as a train approaches.

Calgary Transit has installed left turn gates in this configuration at one of its LRT crossings (see Figure 3-4). When lowered, the left turn gates extend across the two dedicated left turn lanes of a major one-way street running parallel to LRT tracks. These gates are installed at Calgary Transit's 12th Avenue NE grade crossing. Note the concrete barriers installed between the LRT track and left turn traffic lanes.

For this configuration, the left turn gate is located on the inside shoulder of the left turn lane between the tracks and curb of the street running parallel to the tracks. There must be enough room between the tracks and the street edge of pavement to provide for train clearance and vehicle safety. The amount of right-of-way required depends on the train clearance requirements of the operating agency or railroad as well as traffic clearance requirements. For the Metro Blue Line, minimum clearance requirements are governed by CPUC General Orders 26-D and 143-B; by the Manual On Uniform Traffic Control Devices (MUTCD); by the clearance requirements of the Union Pacific Railroad (UPRR); and by the LRT train dynamic envelope clearances specified by the LACMTA.

Figure 3-4
LEFT TURN GATES AT CALGARY TRANSIT 12TH AVENUE NE CROSSING

For the Metro Blue Line if installed adjacent to the LRT track, this configuration would require a minimum clearance of approximately 14 feet, three inches between the centerline of the tracks and the face of the vertical curb of the parallel street (see Figure 3-5).

The MUTCD calls for a minimum distance of two feet from the face of the vertical curb to the closest part of the gate arm assembly in its upright position. Where there is no curb, the MUTCD requires a minimum horizontal clearance of six feet from the edge of the traveled roadway to the closest part of the gate arm assembly. The distance between the outside edge of the flasher background, which is the closest part of the gate arm assembly signal to the face of the vertical curb, and the crossing gate mast or pole varies depending on the size of the background. For this example, the distance is shown as two feet, one inch based on a 20-inch background. With a 24-inch background, the distance would be two feet, five inches. On the other side of the gate arm assembly as shown in Figure 3-5, there must be space for the gate counterweights when the gate is lowered. The distance required for the gate counterweights will vary depending on the length of the gate arm and on the manufacturer of the gate assembly. The distance from the centerline of the crossing gate mast or pole to the outside edge of the counterweights may be as much as four feet, seven inches. In Figure 3-5, this distance is shown as three feet, six inches. CPUC General Order 143-B requires a minimum clearance of one foot, six inches between any wayside equipment and the LRT train dynamic envelope in areas where pedestrians or operating personnel are not expected to be when trains are running. At the car roof corner, the LRT train dynamic envelope clearance is approximately five feet, two inches. Based on these measurements, the total minimum clearance between the centerline of the LRT track and the face of the vertical curb of the parallel street is 14 feet, three inches.

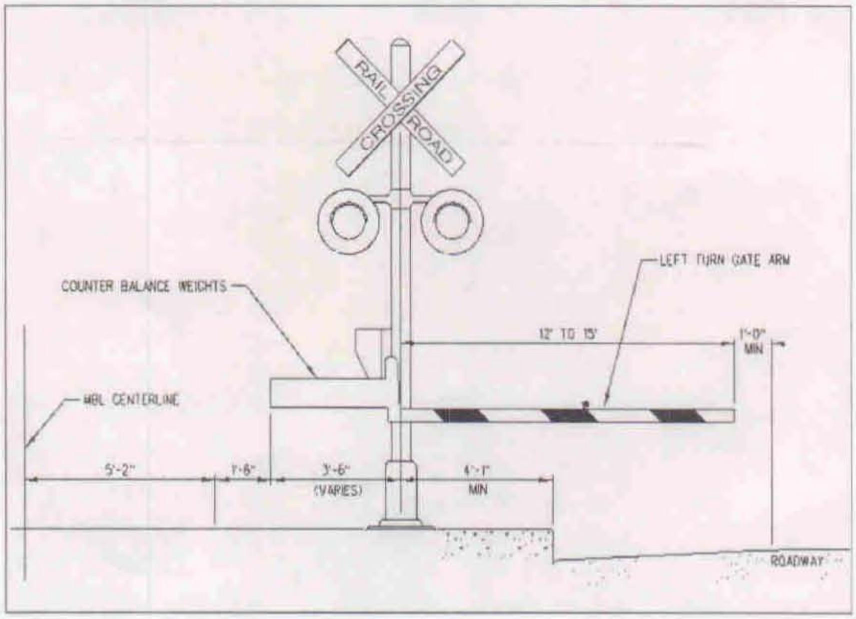

Figure 3-5
EXAMPLE LEFT TURN GATE CONFIGURATION

The UPRR operates freight trains on a track that runs parallel to the Long Beach Blue Line tracks. If installed in the right-of-way adjacent to the UPRR track, this left turn configuration would require a minimum clearance of 19 feet, one inch from the centerline of the track to curb face of the street running parallel to the track. This distance assumes signal flashers with a 20-inch background. The minimum horizontal clearance would be increased to 19 feet, five inches for flashers with a 24-inch background.

The UPRR requires a minimum clearance of 15 feet between the centerline of its tracks and the centerline of a crossing gate mast or pole. Note that this minimum clearance is based on crossing gates which are installed parallel to the track, not crossing gates which are installed at 90 degrees to the track. Also note that this distance is greater than the distance required by CPUC General Order 26-D. CPUC General Order 26-D requires a minimum distance of 12 feet from the centerline of the track to the centerline of the crossing gate mast or pole, based on a minimum horizontal clearance of eight feet, six inches from any wayside equipment plus a distance of three feet, six inches measured from the centerline of the crossing gate mast or pole to the outside edge of the counterweights or flasher hoods. Both the MUTCD and the American Association of Railroads (AAR) Signal Manual show 12 feet as the minimum distance horizontal clearance for typical crossing gate installations.

This configuration is applicable for grade crossings where there is one-way traffic running parallel to the tracks. It might be possible to install this configuration for left turn traffic lanes where there is a street with traffic in both directions running parallel to the tracks. This would require that there be a raised concrete median or island for the installation of the left turn gate, or if not already in place, that a raised concrete median or island be constructed. The minimum width required to construct a median or island of this type, including pavement striping on each side of the median, is approximately ten feet. Construction of the median would require taking additional right-of-way and costly street widening construction. Generally, the cost of the additional right-of-way and construction work would prevent this type of installation from being practicable.

3.2 CONFIGURATION 2: LEFT TURN GATE PARALLEL TO TRACKS AND LEFT TURN LANE

This configuration consists of installing a standard railroad crossing gate, at least 12 feet long and perhaps longer, that, when lowered, extends parallel to the tracks and to the left turn lane across one or more traffic lanes that exit the track area. The lowered left turn gate partially blocks entry into the grade crossing for both left turn and through traffic, in particular making it more difficult for motorists making left turns from the street running parallel to the tracks to enter the crossing in front of an approaching train. Unlike the first configuration, this configuration does not prevent motorists from driving forward in the left turn lane, but the lowered gate makes it difficult for motorists to turn left and drive through the crossing.

This configuration partially blocks entry into the grade crossing for through traffic but through traffic is not prevented from driving around the lowered crossing gates. When lowered, there is a large gap between the left turn gate and the gate installed in the usual quadrant of the crossing to block traffic from entering the crossing.

Calgary Transit has installed left turn gates in this configuration at its 20th Avenue NE LRT crossing. A view of this crossing, with the left turn gates lowered, is shown in Figure 3-6. Note the large gap between the lowered gate arms. These gates were initially installed in the same configuration as described above for the 12th Avenue NE crossing, with the gates at 90 degrees to the left turn lane. The gates were turned parallel to the left turn lanes and LRT tracks due to problems with the gate arms hitting vehicles in the left turn lane as they were lowered.

Figure 3-6
LEFT TURN GATES AT CALGARY TRANSIT 20TH AVENUE NE CROSSING

Using the Metro Blue Line as an example, this configuration requires a minimum clearance of approximately 13 feet, four inches between the street curb face and the centerline of the LRT track. The minimum clearance distance will vary depending on the size and configuration of the crossing gate flashers. Clearance requirements from the LRT track are shown in Figure 3-7. If installed in the right-of-way adjacent to the UPRR track, this configuration would require a minimum clearance of approximately 19 feet, one inch from the centerline of the track to curb face of the street running parallel to the track, depending on the size and configuration of the crossing gate flashers.

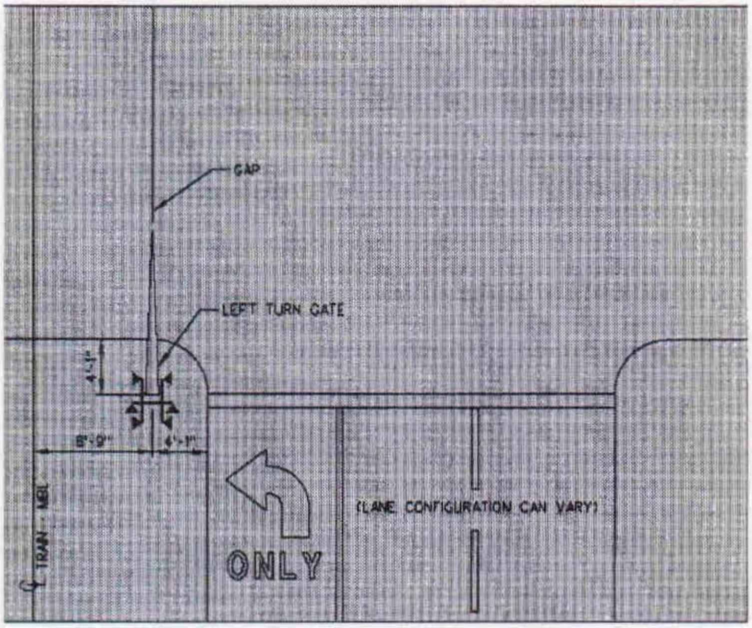

Figure 3-7
EXAMPLE LEFT TURN GATE CONFIGURATION

Crossing gates are installed in this configuration at the Broad Street crossing on NJ Transit's North Jersey Coast line in Red Bank, New Jersey. In Figure 3-8, views of the crossing gates at the Broad Street crossing are shown. Note that there is a gap of approximately 20 feet between the tips of the gates when they are lowered. Traffic volumes at this crossing are heavy and there is frequent commuter train service on two tracks. The crossing is protected with traffic signals as well as automatic gates, flashing lights, and bells. Left turns into the track area may be made from Newman Springs Road which runs parallel to the tracks on the south side of the tracks. There is two-way traffic on Newman Springs Road.

A variation of left turn gates in this configuration are installed at two other NJ Transit commuter rail crossings. At each of these crossings, a left turn gate has been installed on one side of the crossing only. The left turn gates are installed parallel to the tracks but at an angle of about 45 degrees to the street from where the left turns are made into the track area. The crossings are at Bridge and Monmouth Streets in Red Bank and at Fifth and Chelsea Streets in Long Branch. Sketches showing the configuration of each crossing and the placement of the left turn gates are shown in Figures 3-9 and 3-10. Figure 3-11 shows a view of the left turn gate at Fifth and Chelsea Streets, looking east on Chelsea Street with the left turn gate up. At these locations, there is a gap of 15-20 feet between the tips of the gates when they are lowered.

Figure 3-8
VIEW OF LEFT TURN GATES AT NEW JERSEY TRANSIT BROAD STREET CROSSING

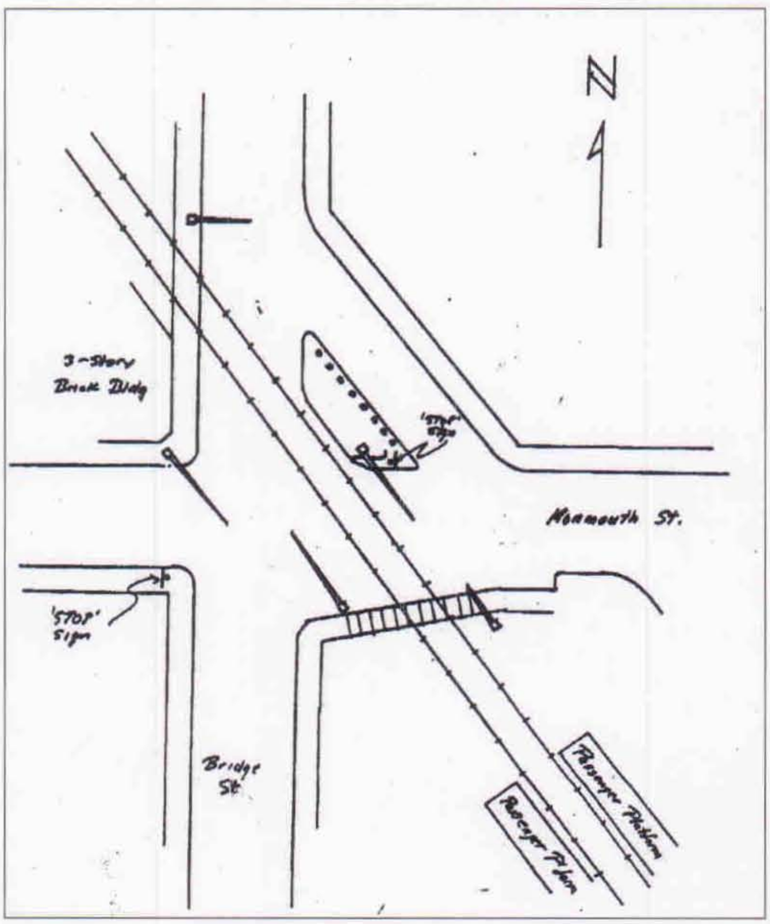

Figure 3-9
LEFT TURN GATE AT NEW JERSEY TRANSIT BRIDGE STREET/MONMOUTH STREET CROSSING

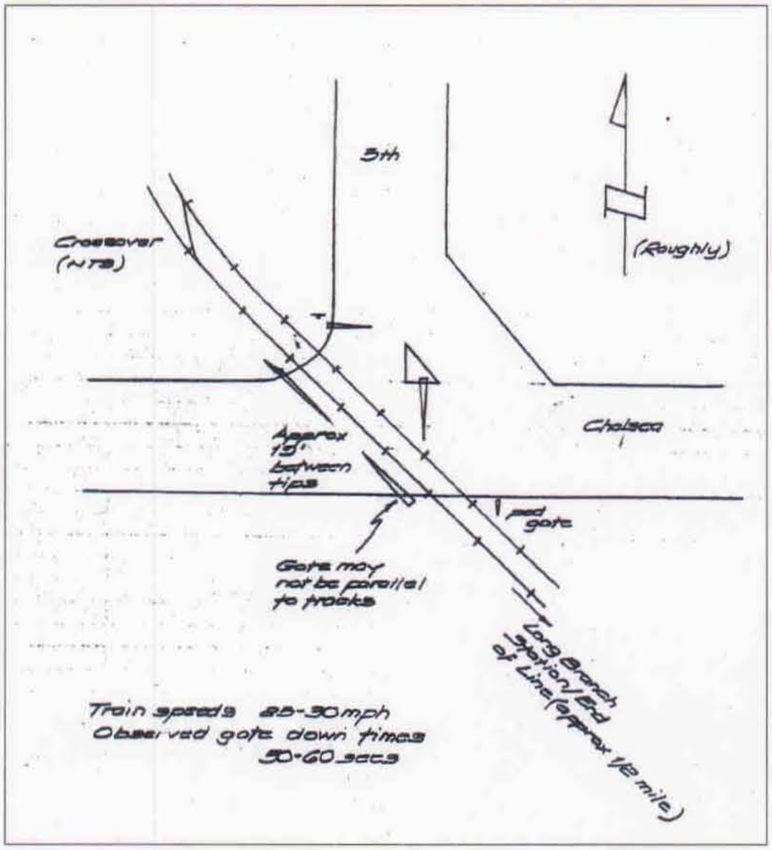

Figure 3-10
LEFT TURN GATE AT NEW JERSEY TRANSIT FIFTH STREET/CHELSEA STREET CROSSING

Figure 3-11
VIEW OF LEFT TURN GATE AT NEW JERSEY TRANSIT FIFTH STREET/CHELSEA STREET CROSSING

At intersections where the street running parallel to the tracks is one-way, this configuration should be effective at preventing motorists making a left turn from entering the grade crossing in front of an approaching train. The turning radius for making left turns is restricted by the left turn gate, making it difficult for a motorist making a left turn to maneuver through the gap between the lowered gate arms.

At intersections where the street running parallel to the tracks is two-way, it is expected that this configuration would be less effective at preventing motorists making left turns from entering the grade crossing. In this case, there is a larger turning radius for making left turns, and motorists could maneuver through the gap between the lowered gate arms.

3.3 CONFIGURATION 3: FOUR QUADRANT OR FULL CLOSURE CROSSING GATE SYSTEM

The third configuration consists of a standard railroad crossing gate that, when lowered parallel to the tracks at the same time as the crossing gate installed in the usual quadrant, completely blocks traffic from entering the crossing. Through traffic as well as traffic making left turns from streets running parallel to the tracks are blocked using this configuration. When installed on both sides of the tracks, this configuration serves to fully block traffic from entering the crossing in front of approaching trains. This configuration, where the crossing is completely blocked when the gates are lowered, is typically referred to as a four quadrant crossing gate system. In fact, all three configurations involve the use of crossing gates in all four quadrants and, therefore, could be referred to as four quadrant crossing gate systems.

This configuration can be installed at grade crossings where traffic on the streets parallel to the tracks is either one-way or two-way. The minimum clearance requirements for this configuration are the same as the clearance requirements for the second configuration.

When all the gates are lowered, the grade crossing is completely blocked off. For this reason, it is important to insure that motorists are not trapped inside the lowered gates as a train approaches. The gates blocking the exits from the crossing area should not be lowered until the gates blocking entry to the crossing area have been lowered so that there is some additional time for motorists in the track area to exit safely from the crossing. The installation of inductive loops to detect vehicles trapped in the track area can also be incorporated into the four quadrant grade crossing system. If a vehicle is detected in the grade crossing as a train approaches, the gates blocking the exits from the crossing area will be held up or returned to their upright position until the vehicle clears out of the crossing.

3.4 CONFIGURATION 4: "POP UP" DELINEATORS

"Pop up" traffic delineators could be used as a left turn barrier at grade crossings where there is insufficient space for the installation of railroad crossing gates.

The City of Los Angeles Department of Transportation (LADOT) has investigated the use of "pop up" traffic delineators to block traffic making left turns across the Long Beach Blue Line tracks at certain signalized intersections. Specifically, the LADOT investigated a "pop up" programmable delineator system available from Tele-Spot Systems of Stamford, Connecticut.

The Tele-Spot Systems product has been used for high occupany vehicle lanes, freeway ramp and lane closures, and parking management applications. The delineators, constructed of a lightweight durable plastic, are installed in the pavement and are controlled to "pop up" when needed (see Figure 3-12). The delineators are able to withstand impacts from vehicles without damaging either the vehicle or the delineator.

Figure 13: Tele-Spot "Pop Up" Delineator System

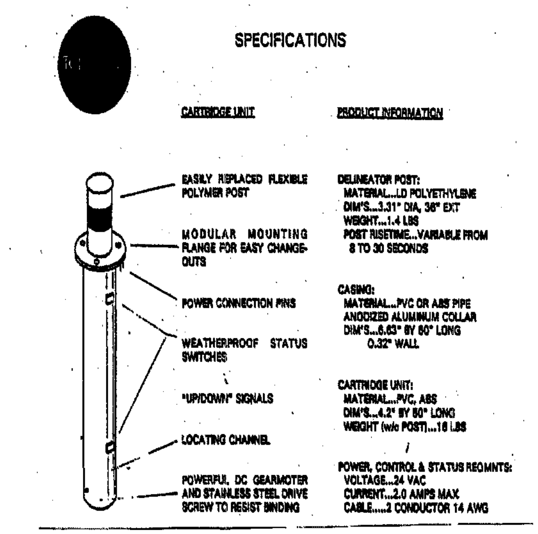

Figure 3-12
EXAMPLE POP-UP DELINEATOR SYSTEM

Discussions between LADOT and the supplier concluded that the "pop up" delineators could not be used for the left turn barrier application. It was determined that the delineators would not be able to perform the number of daily "up and down" cycles required at a grade crossing. If used, the delineators would need to cycle every time an LRT train approached the intersection, more than 200 cycles per day, without failure. The delineator has been designed for two to three cycles per day. Also, it was determined that the delineators could not be raised and lowered quickly enough. The minimum risetime for the delineator posts to be raised to their full upright position is eight seconds. The minimum time required for the delineator posts to be lowered flush with the street surface is also about eight seconds. To be effective as a left turn barrier, the delineator posts would need to be raised and lowered more quickly than is possible with the Tele-Spot Systems product.

There were also concerns about pedestrians causing the delineators to be retracted, by either accidental or intentional contact with one of the delineators as it was being raised. Also, there were concerns about the need to install advance warning signs in conjunction with the delineators so that motorists did not react in an unsafe way to the sudden appearance of delineators in the left turn lane as well as concerns about system reliability and maintainability.

At this time, there is no available product which could be used as a "pop up" barrier to block left turns across the tracks at grade crossings. The use of "pop up" delineators as barriers for blocking left turns in front of approaching trains at grade crossings is not feasible at the present time but could be possible in the future if a suitable delineator system is developed.

3.5 FINDINGS AND CONCLUSIONS

Standard railroad crossing gate equipment can be installed in one of three left turn gate configurations. The use of any one of the left turn gate configurations should serve to reduce the number of train/vehicle collisions involving vehicle making left turns from streets running parallel to the tracks. While not widely used, there are crossings where railroad crossing gates have been installed to block motorists making left turns. Examples have been identified and were described in the report. There are minimum clearance requirements and other restrictions that may prevent the use of one or more of the configurations at a grade crossing. Table 3-1 provides a summary of the key characteristics of the three left turn configurations.

Concurrently with this project, the LACMTA conducted a trial installation of full closure crossing gates at the Metro Beach Blue Line 124th Street crossing. The trial installation included the installation of a trapped vehicle detection system, the first of its kind in North America, to detect the presence of vehicles in the track area. By holding the exit gates up or by driving the exit gates up if they have already started down when a vehicle is detected in the track area, the risk of a vehicle being trapped between the lowered gates has been minimized.

At the 124th Street crossing, there are streets running parallel to the tracks on both sides of the tracks. A critical contributing factor for accidents at this crossing, and at other crossings on the Metro Blue Line where there are streets running parallel to the tracks, is motorists making left turns around the lowered crossing gates in front of approaching LRT or UPRR trains. The trial installation of full closure crossing gates, with a trapped vehicle detection system, will determine the effectiveness of this crossing gate configuration in stopping motorists from making left turns from the streets running parallel to the tracks in front of approaching trains.

Other types of barriers, such as "pop up" delineators, might be used where there is insufficient space for railroad crossing gates. At this time, there is no available product which could be used as a "pop up" barrier to block left turns across the tracks at grade crossings. The use of "pop up" delineators as barriers for blocking left turns in front of approaching trains at grade crossings is not feasible at the present time.

Table 3-1
SUMMARY OF LEFT TURN GATE CONFIGURATIONS

Ref	Left Turn Gate Configuration	Block Left Turns From Parallel Streets	Block S-Turns By Through Traffic	Traffic On Parallel Streets	Typical Right Of Way Required/ LRT	Typical Right Of Way Required/ Freight Railroad	Potential Risk For Trapping Motorists In Track Area
1	Left Turn Gate At 90 Degrees To Left Turn Lane	Yes	No	One Way	14'-3"	19'-1"	None
2	Left Turn Gate Parallel To Tracks and Left Turn Lane	Yes	Possible	More Effective For One-Way	13'-4"	19'-1"	Minimal
3	Four Quadrant Or Full Closure Crossing Gate System	Yes	Yes	One-Way Or Two-Way	13'-4"	19'-1"	High
	Four Quadrant Or Full Closure Crossing Gate System With Trapped Vehicle Detection System						Minimal

4. FULL CLOSURE CROSSING GATES TRIAL INSTALLATION

Full closure or four quadrant crossing gates are potentially the most effective configuration for left turn gates at highway railroad intersections. Concurrently with this project, the LACMTA conducted a trial installation of a full closure crossing gate system at the 124th Street crossing of the Metro Blue Line and UPRR Wilmington Branch Line in the County of Los Angeles. The evaluation of the full closure crossing gates at the 124th Street crossing was carried out as part of this project.

The potential hazard associated with the deployment of full closure crossing gates relates to the possibility of trapping motorists in the track area when the gates are lowered. In order to minimize the possibility of trapping a motorist in the track area behind the lowered crossing gates, the system at the 124th Street crossing incorporated exit gates that fail safe in the up position; a delay in lowering the exit gates to allow motorists in the track area to exit from the track area; and a track area highway vehicle detection system that was carefully designed to detect vehicles in the crossing area and cause, by interrupting the gate down control circuit, the exit gates to be held up or, if the exit gates have already started down, to be returned to their vertical position. The track area highway vehicle detection system was implemented on an open architecture VMEbus-based transportation controller meeting the Caltrans Type 2070 specification. A series of inductive vehicle detection loops were installed in the track area and are used to detect vehicle presence. These loops are similar to, but not the same as, vehicle detection loops which are widely used throughout North America for a variety of traffic control and surveillance applications, under a wide variety of climatic and environmental conditions.

4.1 PROJECT BACKGROUND

The Metro Blue Line Grade Crossing Safety Improvement Program, initiated by the LACMTA Board of Directors in 1993, consisted of a number of individual projects designed to enhance public safety at the 100 at-grade crossings on the Metro Blue Line. The Metro Blue Line, opened in mid-1990, is a light rail transit line which runs a distance of 22 miles from downtown Los Angeles to downtown Long Beach.

One of the safety improvement projects has involved the deployment of a full closure crossing gate system at the 124th Street grade crossing. It was determined to conduct the trial installation of four quadrant gates in order to evaluate the potential of full closure crossing gates for reducing the number of accidents at crossings where there are streets running parallel to the tracks and where there may be LRT and freight trains at the same time. The evaluation of the full closure crossing gates was carried out under this FTA-funded project.

4.1.1 California Public Utitlites Commission (CPUC) Resolution

The operation of the experimental full closure crossing gates system at the 124th Street crossing required CPUC approval. The LACMTA requested CPUC approval for the trial installation in April 1995, pursuant to Section 12.2 of CPUC General Order 75-C. The trial installation was to be conducted for a period of one year at the intersection of 124th Street with the Metro Blue Line and the immediately adjacent Southern Pacific Transportation Company (now, Union Pacific Rail Road) Wilmington Branch Track. CPUC Resolution SX-12, dated September 7, 1995, provided the necessary approval to proceed with the trial installation.

4.1.2 Project Stakeholders

The project was conducted by the LACMTA with the cooperation of the UPRR and the Los Angeles County Department of Public Works. The LACMTA Office of System Safety and Security has been responsible for project planning, management, and coordination. PB Farradyne is serving as the LACMTA's Project Engineer, working under task orders from the Engineering Management Consultant (EMC), a joint venture of Parsons Brinckerhoff and DMJM which has been serving as the LACMTA's General Engineering Consultant.

Key technical assistance for the project has been provided by the LACMTA Signal Maintenance Department; by traffic signals systems personnel in the Los Angeles County Department of Public Works Operational Services Division; Safetran Systems Corporation; and EMC specialist subconsultants, Rail Safety Engineering and James Moe.

4.2 PROJECT LOCATION

The 124th Street crossing of the LACMTA Metro Blue Line and UPRR Wilmington Branch is identified by CPUC Crossing Numbers 84L-10.1 and BBH-492.33 and by FRA Crossing No. 747867J. It is located in the Willowbrook area of south central Los Angeles County about one mile south of the I-105 Freeway.

There are three tracks at the crossing, running generally in a north-south direction. The Metro Blue Line normally northbound and normally southbound tracks run on the east side of the crossing, and one UPRR track runs parallel to the Metro Blue Line tracks on the west side of the crossing. Willowbrook Avenue runs parallel to the tracks on both the east and west sides of the tracks. There is two-way traffic on Willowbrook Avenue West and Willowbrook Avenue East.

On the average, there are approximately 230 LRT trains and 16 UPRR freight trains passing through the crossing each day. LRT train volumes are lower on Saturdays and Sundays, and LRT trains are not operated in revenue service between about 1:00 a.m. and 4:30 a.m. each night. There are two trains in the crossing at the same time approximately 20 times per day.

The crossing is situated in a predominantly residential area. 124th Street is three lanes wide through the crossing, with one through traffic lane in each direction and back-to-back left turn lanes for eastbound and westbound traffic in the center of the roadway between the through lanes. The two-way traffic volume on 124th Street averages approximately 1,800 vehicles per day, varying from a few vehicles per hour at night to as high as roughly 150 vehicles per hour during peak hours. Pedestrian traffic at the crossing is light, averaging about 16 pedestrians per hour in both directions.

The streets are surfaced with asphalt concrete pavement. The pavement in the track area is in very good condition, except that the pavement adjacent to the UPRR track shows some minor cracking and deterioration. The track crossings are asphalt over timber ties with timbers installed next to the rails, in accordance with Standard No. 2 of CPUC General Order 72-B.

The intersections of Willowbrook Avenue East and Willowbrook Avenue West with 124th Street are controlled by a two-phase traffic signal system with railroad preemption. Activation of the railroad grade crossing warning equipment preempts the traffic signals at the two intersections.

The railroad preemption sequence provides a green clearance interval for vehicles queued into the track area. During preemption for light rail trains, traffic on Willowbrook Avenue running parallel to the tracks receives a green signal with a red left arrow displayed for left turns across the tracks. During UPRR train preemption, traffic on Willowbrook Avenue receives a flashing red signal with a red left arrow displayed for left turns across the tracks.

Advance warning times for Metro Blue Line LRT trains are approximately 24 seconds based on fixed length audio frequency approach track circuits with the LRT trains operating at the signaled speed limit, 55 miles per hour. Advance warning times for UPRR freight trains are constant at approximately 35 seconds using Safetran GCP-3000 grade crossing predictor equipment. The UPRR track speed is 35 miles per hour. The UPRR upgraded portions of the Wilmington Branch, including the territory at the 124th Street crossing, for centralized computer-controlled train operations in early 1999.

4.3 SYSTEM OPERATION

Traffic control equipment at the crossing includes four CPUC No. 9 automatic gate and flashing light assemblies, configured so that entry for highway vehicles into the track area is completely blocked when the gates are down. Traffic control equipment at the crossing also includes traffic signals at the intersections on both sides of the tracks. The automatic gate and flashing lights in the southwest quadrant of the crossing, adjacent to the UPRR track, are operated and maintained by the UPRR. The automatic gates and flashing lights installed in the other three quadrants of the crossing, including the exit gate and flashing lights on the west side of the crossing (adjacent to the UPRR track), are operated and maintained by the LACMTA. Both the LACMTA and UPRR provide the XR repeater relay contacts to the other in order to activate each other's crossing equipment when there is a train approaching the crossing.

A gate down call may be initiated by a LRT or UPRR train. As soon as the gate down call is made, the flashers are activated and are on for three seconds before the entrance gates, in the southwest and northeast quadrants of the crossing, are started down. Both entrance gates are down at about 12 seconds after the flashers are activated, which corresponds closely with the end of the track clearance green signal for traffic in the track area. For the trial installation, the exit gates, in the southeast and northwest quadrants, were delayed in starting down by three to seven seconds after the entrance gates started down using a vital timer (unless there was a vehicle detected in the track area). The vital timer allowed for the exit gate start down time delay to be adjusted. For most of the trial installation period, the exit gates were started down after a delay of five seconds from when the entrance gates started down (at this time, the entrance gates are roughly at 45 degrees from vertical). The exit gates, delayed by five seconds after the entrance gates in starting down and not held up for a vehicle detect, are down at about 16 seconds after the gate down call is initiated or about eight seconds in advance of an LRT train entering the crossing (or about 19 seconds in advance of a UPRR freight train entering the crossing).

The system incorporates a number of self-checking features to detect equipment or circuit malfunctions, including malfunctions of the track area vehicle detection loops and associated equipment, broken exit gate arms, loss of system controller power, and any problems with the operation of the "go/no go" relays where the interface between the system controller and the railroad exit gate down control circuits is implemented. When a malfunction is detected, the system controller generates an alarm, which is reported at the Rail Operations Center, and shuts itself down. When the system controller is shut down, the exit gates will remain in their up position until the system controller is re-started by a Rail Operations Supervisor or Signal

Systems Maintainer. Detailed alarm response procedures were prepared and incorporated as part of the standard LRT operating procedures for the trial installation.

4.4 SYSTEM COMPONENTS

The system, as currently installed and operational at the 124th Street crossing, consists of the following components.

- Track area elements, including vehicle detection loops, stacked test loops, pullboxes and conduit runs, and exit gates;
- Trapped vehicle detection system controller (also referred to as Exit Gate Controller or EGC);
- Exit gate control and power supply circuits;
- Intersection event recorder;
- Intersection video surveillance; and
- Rail Operations Center alarm points.

Figure 4-1 summarizes the system components and their interconnections. Note that there is a clearly defined interface, both logically and electrically, between the track area vehicle detection system and the railroad circuits and related equipment that control the operation of the crossing gates. For on-going operations, the interface allows system maintenance responsibilities for both the traffic and railroad equipment to be clearly delineated.

Figure 4-2 shows the layout of the 124th Street crossing, including the placement of the track area vehicle detection loops, exit gates installed for the four quadrant gates, and related equipment.

A description of the individual system components follows.

4.4.1 Track Area Elements

The track area elements are as follows.

- **Vehicle Detection Loops**. Eight loops have been installed in the track area to provide as much coverage of the track area as possible. The loops are large and rectangular in shape, varying in size from 60 square feet to 200 square feet. Each loop consists of three turns of Caltrans-standard loop wire. The loop corners are cut at an angle to minimize the loss of detection at the loop corners.

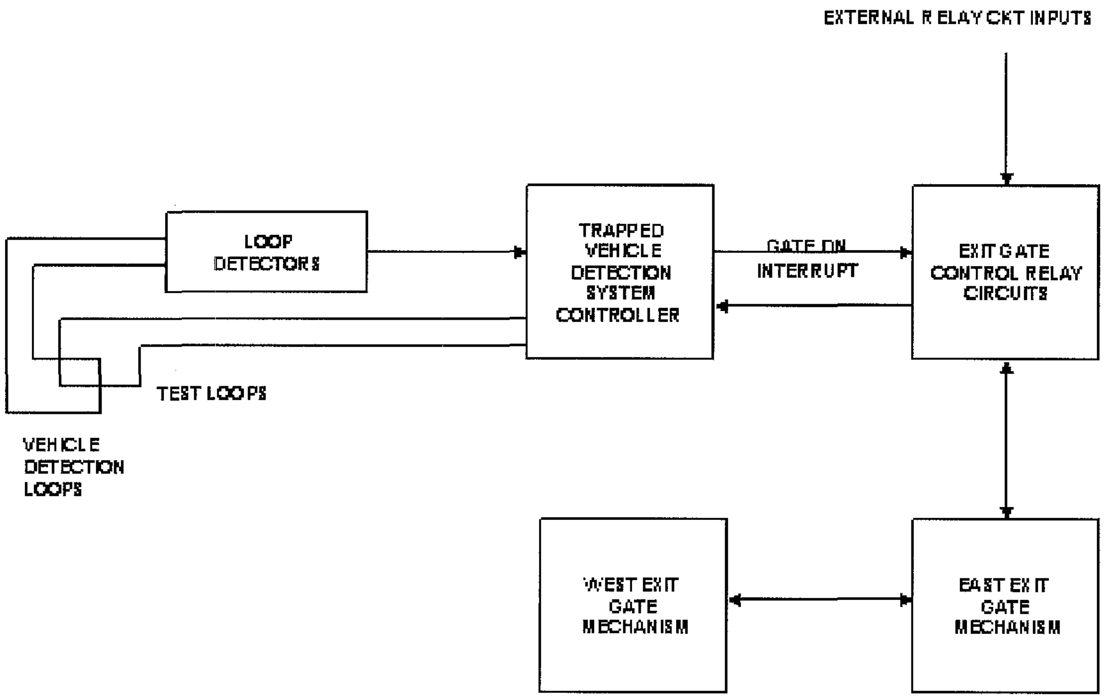

Figure 4-1
FULL CLOSURE CROSSING GATE SYSTEM SCHEMATIC

The loops are offset by one foot, or nearly so, from the crossing surface timber to allow room for the re-cutting of the loop without affecting the loop coverage area, should that be required in the future. The loops are offset by approximately one foot from the edge of pavement on both sides of the street.

The loop-to-loop distance, measured at right angles to each track and across each track, is 8'-10" for all loop pairs. The angled configuration of the crossing assists for vehicle detection, as the front left corner and right rear corner of vehicles are detected at distances less than the loop-to-loop distance measured at right angles to the tracks. The ends of the loop wires for each of the eight loops are spliced at pullboxes located at the side of the roadway to detector lead-in cables, which run in conduits to the control case.

The vehicle detection loops were tested in advance of system operation. A motor vehicle, 12'-5" long and 5'-0" wide, was used to verify continuous detection in the track area. It was required that there is continuous detection of the test motor vehicle along three alignments through the track area – one alignment centered on the through traffic lanes in each direction; one alignment centered on the street center line; and one alignment where the right hand side of the test vehicle was offset by one foot from the edge of pavement.

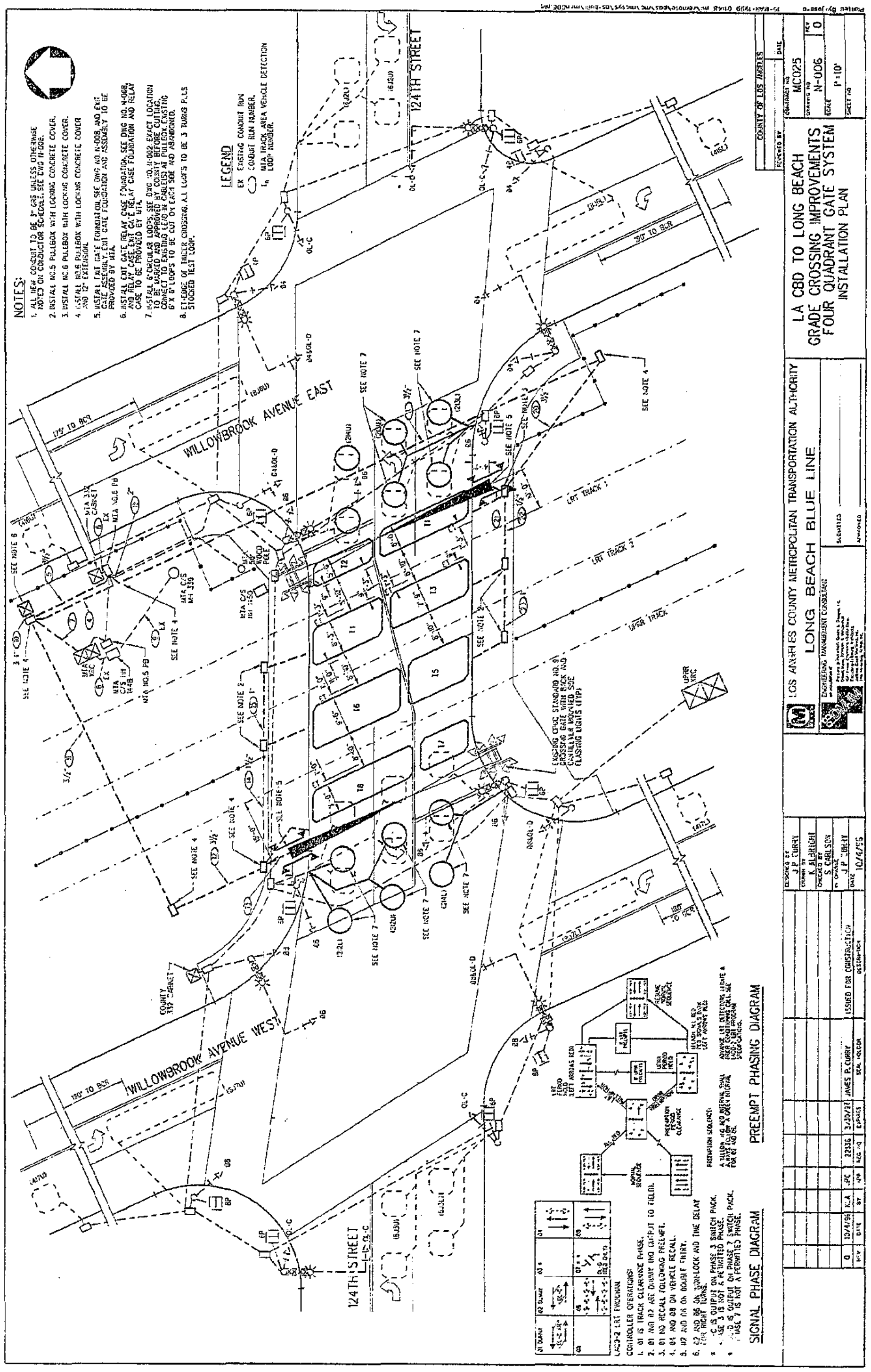

Figure 4-2
FULL CLOSURE CROSSIN G GATE SYSTEM INSTALLATION PLAN

Figure 4-3
VERIFYING TRACK AREA VEHICLE DETECTION LOOP COVERAGE

- **Stacked Test Loop**. The vehicle detection system incorporates a unique design for the detection loops that provides for fail-safe operation. A one-turn loop is stacked on top of each vehicle detection loop, in the same saw cut, to provide for periodic loop testing. When the circuit that includes the one-turn loop is closed, the inductance of the vehicle detection loop is changed so that a vehicle presence is recorded by the sensor unit, verifying that the loop circuit and sensor unit are functional. At 124th Street, this test is initiated each time that the gates are called down by a LRT or UPRR train, before the track area is checked for vehicle presence and a "go/no go" decision is made to lower the exit gates.

  This approach allows for the "simulation" of vehicle presence, without inserting additional devices into the loop circuit. After being installed and tested at the 124th Street crossing, the LACMTA shared this approach with FRA, FTA, Amtrak, and others interested in track area vehicle detection, and the stacked test loop approach is currently being used at other locations where four quadrant gates are installed.

- **Exit Gates.** The exit gates are controlled by Safetran S-20 gate mechanisms, modified so that the gates are driven down and held down (see Figure 4-4), and counterweighted so that the gates will fail safe in the up, not down, position. When failed in the up position, the exit gates rest at an angle of about 80 degrees from horizontal.

  The exit gate down control circuit includes the gate arm lamp circuits on both exit gates. If one of the exit gate arms is broken so that the gate arm lamp circuits are broken, the exit gates will be returned to or held in the up position. After three trains have traversed the crossing with the exit gates up, the system controller will generate an alarm, which is reported at the Rail Operations Center, and will shut itself down. The exit gates will remain in their up position until the system controller is re-started by a Rail Operations Supervisor or Signal Systems Maintainer.

  Note that broken exit gate arms are detected automatically only if the gate arm continuity circuit is broken. It is not possible to detect a broken gate arm by monitoring cam contact closures in the gate mechanism.

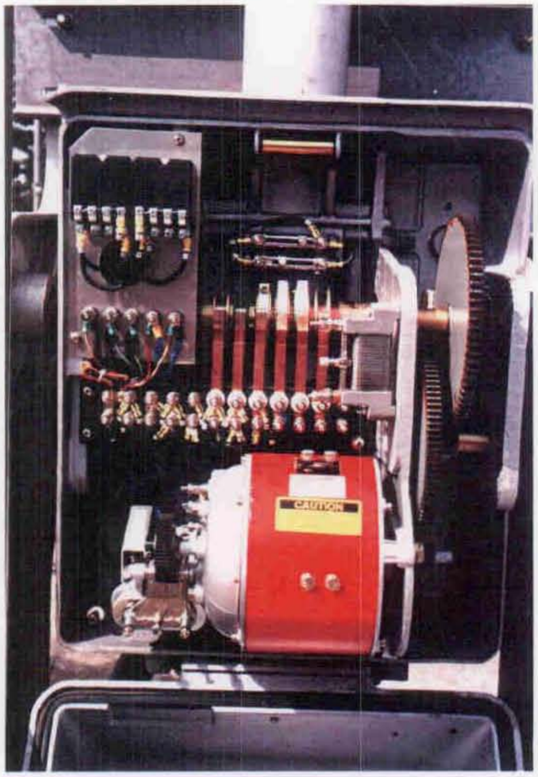

Figure 4-4
MODIFIED SAFETRAN S-20 GATE MECHANISM

4.4.2 Trapped Vehicle Detection System Controller

The trapped vehicle detection system controller and related components are standard traffic signal control equipment. The equipment is designed to be rack or shelf mounted, requires a 115VAC commercial power source, and is housed in a separate Caltrans standard 332 traffic equipment cabinet. The system components housed in the traffic cabinet are as follows.

- **Inductive Loop Vehicle Detectors**. The detector electronic units (or just detectors or sensors as they are commonly called) are connected to the vehicle detection loop circuits. The detectors provide a contact closure output to indicate the presence of a vehicle over the loop when there is a change in inductance in the vehicle detection loop circuit that exceeds a specified level. The negative change in loop circuit inductance, when a vehicle is present over the loop, results in a change in the resonant frequency of the loop circuit which can be measured digitally by the detector. This is accomplished by providing an excitation voltage to the loop circuit and then continuously monitoring for frequency changes.

  The detectors being used at the 124th Street crossing are Intersection Development Corporation (IDC) Detector Systems Model 262FCR detectors. These are rack-mounted NEMA Type 7T detectors that provide two channels, self tuning, nine sensitivity settings (for changes in inductance from 0.0025 percent to 0.64 percent), three operating frequencies (between 20 and 50 kHz), and a separate contact closure output to indicate that the loop circuit has failed with a short to ground or a break in the loop circuit. Loops operating on the two channels are scanned sequentially to eliminate, or minimize, crosstalk between the loops connected to these channels. Loops which are adjacent to each other but not connected to the same detector are operated on different frequencies to eliminate crosstalk. Crosstalk between adjacent track area loops was a major concern during system design and testing but was never a problem during the operation. Note that the vehicle detect relay is energized when there is no vehicle detect and deenergized when there is a vehicle detected or when power is lost.

- **System Controller**. The trapped highway vehicle detection system has been implemented on an open architecture VMEbus-based advanced transportation controller that meets the Caltrans 2070 specification. The 2070 controller hardware used at 124th Street was obtained from Eagle Traffic Control Systems. This controller hardware represents the latest generation of field computers or advanced transportation controllers that are being implemented throughout North America to support the traffic monitoring and processing requirements of intelligent transportation system applications.

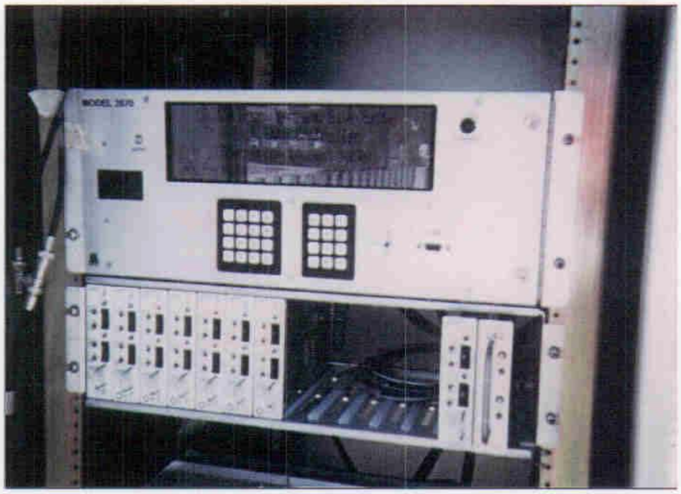

Figure 4-5
FRONT VIEW OF SYSTEM CONTROLLER AND LOOP DETECTORS

For the vehicle detection application developed and implemented at the 124th Street crossing, three of the four expansion slots in the controller chassis are being used. One slot has a CM-DI-20 16-channel optocoupled input board to handle the eight inputs required from the railroad gate down control circuits. The inputs include both approach and island track circuit occupancy indications for LRT and UPRR trains; exit gate down indications for the east and west exit gates; and indications concerning the status of the back contact closures for the "go/no go" repeater relays. Two slots are equipped with CM-DO-20 16-channel relay/optocoupler output boards that provide output contact closures to activate the test loops and, implemented separately on each board, redundant "go/no go" relays (both of which must be energized in order to pick the "go/no go" repeater relays that enable the exit gates to be lowered) and, also implemented independently on each board, redundant alarm relays.

- **Application Software**. The 2070-based software has been custom developed for this application. The software is highly structured to assist with verification and validation, and is table driven, where applicable, to assist in portability for other locations (such as to accommodate different track area loop configurations). The real-time and multi-tasking software is written in C under the OS-9 operating system. The OS-9 operating system allows the code to be run on many types of processors including the Intel 80x86 processors and all Motorola 68000 series. Before being taken to the field for testing, the software was extensively tested using a PC-based simulator running both pre-defined scripts and manually-input test sequences.

The application software includes the following functions.

Exit Gate Down Interrupt Circuit Cycle Testing

For each time that the exit gates are called down by a LRT or UPRR train, the interface with the railroad gate down control circuits is verified. Specifically, the two "go/no go" repeater relays in the railroad gate down control circuits are verified, first for one and then for the second (one at a time). The railroad "go/no go" repeater relays repeat the "go/no go" relays on the system controller output boards. Both "go/no go" repeater relays must be picked for the exit gates to be started down or, more importantly in order to prevent trapping a motorist in the track area, at least one of the front contacts must not be closed for the exit gates to be held up.

In order for the exit gates to be lowered, both of the system controller "go/no go" relays and both of the railroad "go/no go" repeater relays need to be energized, with their front contacts closed. In order for the exit gates to be held up, at least one of the railroad "go/no go" repeater relays need to be de-energized, with no front contact closure. This test is designed to verify that the exit gates will be held up in the event that there is a vehicle detect in the track area.

This test is done as soon as an input is received that the gates are being called down (that is, XR or XPR back contact closure) by first energizing, then deenergizing each of the "go/no go" relays at the system controller. When one of the system controller "go/no go" relays is deenergized, it is expected that the corresponding "go/no go" repeater relay will be deenergized, making a back contact closure that is confirmed by an input to the system controller. If that input is not received as expected, the system controller generates an alarm at the Rail Operations Center and shuts itself down. When the system controller is shut down, the exit gates will remain in their up position until the system controller is re-started by a Rail Operations Supervisor or Signal Systems Maintainer.

Loop Cycle Testing

The operation of the detectors and associated vehicle detection loop circuits are verified each time that the gates are called down by a LRT or UPRR train. This is done by energizing relays on the output boards that cause the stacked loop circuits to be closed, and then checking each of the detectors for a vehicle detect indication. If there is no vehicle detect indication as expected, the system controller generates an alarm and shuts itself down. When the system controller is shut down, the exit gates will remain in their up position until the system controller is re-started by a Rail Operations Supervisor or Signal Systems Maintainer.

Track Area Vehicle Detection

The vehicle detect and loop failed outputs from each of the detectors are continuously monitored. A loop failed output is acted upon as soon as a loop failed indication is received. When received, the system generates an alarm and shuts itself down.

When the crossing gates are being called down and both the loop and exit gate down interrupt circuit the cycle tests have been completed, vehicle detects are acted upon to control the operation of the exit gates as follows.

a. If there is a vehicle detect from any of the track area loops, the system controller "go/no go" relays are deenergized so that the exit gate down control circuit, which controls the operation of both exit gates, is interrupted and the exit gates are held up. Since it is not known if the motorist is driving under one of the entrance gates or is making an s-turn around a lowered entrance gate, the logic implemented at the 124th Street crossing provides that both exit gates will be held up or returned to their vertical position if there is a vehicle detect.

b. Vehicle detects are not acted on if there is an island circuit occupied indication, in order to avoid acting on LRT or UPRR train detects. With the vehicle detection loops installed at 4'-5" from the track centers, all trains in the track area will generate highway vehicle detects.

c. Vehicle detects are not acted on for 1.0 seconds after being received but will be acted upon after this time delay has expired as long as there has been a continuous vehicle detect from any of the track area loops. This delay is necessary to accommodate the delay in obtaining the island circuit occupied indications. The island occupied indication for LRT trains is about 1.5 seconds from the time when the train enters the island circuit or about 1.0 second from the time when the train is detected by one or more of the vehicle detection loops.

   The use of the island circuit and the length of the vehicle detect delay required to avoid vehicle detects by trains was a critical system design element and may be even more important for future installations.

d. Vehicle detects generated by the loops closest to the crossing gates on the east side of the crossing, loops 1 and 2, are not acted on when both exit gates are down. This logic was implemented for loops 1 and 2 only due to their proximity to the east crossing gates, and the possibility of a vehicle stopped right on the outside of one of the gates being detected and causing the exit gates to be raised. Vehicle detects generated by any of the other loops are acted on if one or both of the exit gates are down.

   Based on the trial installation results and before permanent operation was commenced, the logic used for vehicle detects on loops 1 and 2 was extended for all track area loops.

<u>Front Panel Data Displays</u>

When activated, a front panel display continuously shows the status of all system controller inputs and outputs, including track area vehicle detects. The front panel display display is password protected.

The front panel display also shows alarm and system error codes required for troubleshooting a system malfunction. When the system controller shuts itself down, the front panel display will show the status of all system controller inputs and outputs at the time when the alarm was generated as well as the error code associated with the system malfunction.

<u>Alarms and Corresponding Error Codes</u>

If a system failure or suspected system failure condition is identified, the system controller generates an alarm with a corresponding error code on the front panel display and shuts itself down. Table 4-1 provides a summary of the alarm and error code conditions, including directions for troubleshooting.

ALARM	ERROR CODE	DESCRIPTION	RECOMMENDED RESPONSE
1	1	Exit Gates Not Down For Three Trains	Broken Gate Arm. Notify Signals Maintenance to replace broken gate arm. When the broken gate arm is replaced, reset the EGC to restore normal operation.
1	1	Exit Gates Not Down For Three Trains	One Or Both Exit Gates Hung Up. One or both exit gates have not returned to their full up position and cam contacts 9 and 10 in one or both exit gate mechanisms are not making a closed contact. The XGPR relay will probably be deenergized and, if so, the exit gate flashers will be continuously on. When the exit gate arms are returned to vertical, reset the EGC to restore normal operation.
1	1	Exit Gates Not Down For Three Trains	Gate Arm Continuity Connector Not Connected. The exit gates will not lower if one or both of the gate arm continuity circuits are open. Notify Signals Maintenance to check and, if necessary, repair the gate arm continuity circuits. When the exit gate arm continuity circuit is repaired, reset the EGC to restore normal operation.
1	1	Exit Gates Not Down For Three Trains	Traffic Signal Power Failure. The EGC is powered by the intersection traffic signal power supply and also has its own backup power supply. In the event of a traffic signal power outage or power supply circuit failure, the EGC will continue to run using its backup power supply but power will be removed from all detectors so that the detectors are providing continuous detect outputs, causing the exit gates to be held up. The exit gate flashers will continue to function when there is approach track circuit occupancy. The condition may have cleared itself or may still be present. If still present, all detector LEDs will be on and the EGC cabinet fan will not be running. If the traffic signals are dark, traffic signal power is off and needs to be restored before normal operation can be resumed. Depending on how long it will require for traffic signal power to be restored, contact Signals Maintenance to remove the exit gate arms or wait until power is restored and reset the EGC to restore normal operation. If the traffic signals are operating and the condition is still present, there has been a failure in the EGC power supply circuits. In this case, it will be necessary to contact Signals Maintenance to remove the exit gate arms until the problem can be resolved by the County Department of Public Works. If the condition has cleared up and there is traffic signal power, reset the EGC to restore normal operation.

ALARM	ERROR CODE	DESCRIPTION	RECOMMENDED RESPONSE
1	1	Exit Gates Not Down For Three Trains	Loop Detector Hung Up. A vehicle detection loop is crosstalking with an adjacent loop or possibly with one or more rails, resulting in a continuous detect output and the exit gates being held up. The condition may have cleared itself or may still be present. If still present, the detect LED for the loop detector that is hung up will be on, or possibly chattering on and off. Reset the detector card, by toggling the MODE switch from its PR/PR setting to its middle PL/PL setting then reset the EGC to restore normal operation. If the condition cannot be eliminated by resetting the detector, it will be necessary for the County Department of Public Works to adjust the detector frequencies. Until this is done, contact Signals Maintenance to remove the exit gate arms.
1	7	Loop Detector Failed	A loop detector circuit or, possibly, a detector card has failed. The number of the detector which has failed will be displayed on the EGC front panel display. The corresponding detect LED will be blinking. Reset the detector card, by toggling the MODE switch from its PR/PR setting to its middle PL/PL setting. Then, reset the EGC to restore normal operation. If the condition cannot be eliminated by resetting the detector and the detect LED continues to blink after the detector has been reset, the detector card may be removed and replaced with one of the spare detector cards. This may eliminate the problem although it is most likely that the problem is due to a short or loose connection in the loop wires. Make sure that the MODE, FREQ, and SENS settings for the new detector card are identical to the settings on the detector card being removed (note that MODE=PR/PR, its up position, and SENS=4 for all detectors). If the condition is not eliminated by replacing the detector card, contact Signals Maintenance to remove the exit gate arms.
1	8	Loop Detector Test Failed To Detect	The EGC was not able to close one of the test loop circuits, indicating a test loop circuit failure. Reset the EGC to restore normal operation. If the condition is not an intermittent one and the ALARM is re-generated after the EGC is reset and at least one train has traversed the crossing, contact Signals Maintenance to remove the exit gate arms and do not reset the EGC again.
1	A	Loop Detector Port Failed.	The EGC or the EGC C1 Connector has failed. Do not attempt to reset the EGC. Contact Signals Maintenance to remove the exit gate arms.

ALARM	ERROR CODE	DESCRIPTION	RECOMMENDED RESPONSE
2	2	XC1NFB OFF; Should Be ON.	The EGC or one of the XC1PR relay has failed, or there is a loose wire or gold nut in one of the exit gate down control circuits. Do not attempt to reset the EGC. Contact Signals Maintenance to remove the exit gate arms.
2	3	XC2NFB OFF; Should Be ON.	The EGC or one of the XC2PR relay has failed, or there is a loose wire or gold nut in one of the exit gate down control circuits. Do not attempt to reset the EGC. Contact Signals Maintenance to remove the exit gate arms.
2	4	XC1NFB and XC2NFB OFF; Both Should Be ON	The EGC or one of the XC1PR or XC2PR relays has failed, or there is a loose wire or gold nut in one of the exit gate down control circuits. Do not attempt to reset the EGC. Contact Signals Maintenance to remove the exit gate arms.
2	5	XC1NFB ON; Should Be OFF.	The EGC or one of the XC1PR relay has failed, or there is a loose wire or gold nut in one of the exit gate down control circuits. Do not attempt to reset the EGC. Contact Signals Maintenance to remove the exit gate arms.
2	6	XC2NFB ON; Should Be OFF.	The EGC or one of the XC2PR relay has failed, or there is a loose wire or gold nut in one of the exit gate down control circuits. Do not attempt to reset the EGC. Contact Signals Maintenance to remove the exit gate arms.
2	B	False Island Circuit Indication.	A LRT or UPRR island circuit occupancy indication has been received by the EGC without a corresponding approach circuit occupancy indication and without the 124XPR relay being deenergized for a duration of at least four (4) seconds. There has been a failure in the LRT or UPRR island circuit occupancy circuits in the EXRC case or EGC cabinet, such as a loose wire or terminal block connection. Do not attempt to reset the EGC. Contact Signals Maintenance to remove the exit gate arms.
Both		Power Failure	The EGC has a backup power supply, adequate to operate the EGC for at least four hours. ALARM 1 with ERROR CODE=1 will be generated in the event of a traffic signal power outage or power supply circuit failure before this ALARM condition is generated. This condition will only occur if traffic signal power is removed and, at the same time, the backup power supply has failed. If the traffic signal power is on, reset the EGC to restore normal operations. If the traffic signal power is off and depending on how long it will require for traffic signal power to be restored, contact Signals Maintenance to remove the exit gate arms or wait until power is restored and reset the EGC to restore normal operation.
Both	WD#	EGC System Failure	The EGC has failed. Do not attempt to reset the EGC. Contact Signals Maintenance to remove the exit gate arms.

4.4.3 Exit Gate Control and Power Supply Circuits

The operation of the exit gates is controlled by relay logic using standard railroad circuits. The exit gates will be held up, or if already started down, be returned to the up position, by interrupting the circuit which provides the gate down control signal to the exit gate mechanisms.

Note that if the exit gates have started down, they are returned to their vertical position before being started back down, regardless of the duration of the highway vehicle detect.

There is a well defined interface with the railroad gate down control circuits. The interface between the highway vehicle detection system and railroad crossing control equipment has been established as the point where inputs are provided from the railroad crossing control circuits and outputs are, in turn, provided from the vehicle detection system controller to the railroad crossing control circuits.

The exit gate control and power supply circuits incorporate the relays listed in Table 4-2.

4.4.4 Event Recorder

The performance of the system is continuously monitored by event recorder data collection as well as by video recording. A Safetran A80250 event recorder, consisting of one A80251 Processor/Display Unit and one A80258 Analog and Digital I/O Unit, with adequate storage, before event data is written over, for nearly three days of event data is being used.

For the trial installation period, the event recorder data was downloaded on a regular basis. There are some short gaps in the data collected, usually related to data collection over a weekend where the data was not downloaded late enough on Friday afternoon or early enough on Monday morning. Each day's event recorder data was analyzed and events, such as the exit gates being held up for a vehicle detect and the exit gates not being down for a train, were identified for followup verification on that day's video tape. The event recorder data was also analyzed to provide a count of each day's gate down calls, two trains at the same time, and abnormal railroad equipment operation. Figure 4-6 shows an example of the reports generated for one day's operation.

4.4.5 Intersection Video Surveillance

The crossing is continuously monitored by video. Video data is continuously transmitted to the Rail Operations Center by microwave. For the trial installation period, the video data was continuously recorded in timelapse mode so that one day's data was recorded on one tape.

Early in the project, two Cohu black and white video cameras were installed on a tall wooden pole in the northeast quadrant of the crossing. The cameras were installed on a cross arm at a height of approximately 38 feet, the upper limit of a fully-extended County bucket truck, and aimed to provide coverage of the track area and limited coverage of the intersection on the west side of the tracks. The pole, video cameras, and microwave transmission equipment were installed at the crossing by the Los Angeles County Department of Public Works.

Table 4-2
EXIT GATE CONTROL AND POWER SUPPLY RELAYS

Relay	Exit Gate Control Function
124EXR	Picked when either SP124XR or 124XPR relay makes back contact closure, indicating that there is a train approaching the crossing.
124EXPR	Field adjustable vital timer relay, adjustable in one second increments. Time delay is initiated when 124EXR is picked.
124EXPPR	Picked when gate down control circuit is not broken, meaning that XC1PR and XC2PR relays are picked; exit gate up cam contacts in both exit gate mechanisms are closed; the gate arm continuity circuits for both exit gates are not broken; and the 124EXPR relay is picked.
SP124GDPPR	Picked when UPRR entrance gate is down. Used for event recording only.
124XGPR	Used to maintain power to the exit gate arm lamps and exit gate assembly flashers until the exit gates are returned to their up positions.
124XEOR	Exit gate assembly flasher relay.
124EXPOR	Power out relay.
XC1PR, XC2PR	Exit gate down "go/no go" repeater relays. Must be picked for exit gates to be started down.
124LRTXOTR	LRT island track circuit repeater relay. Used to provide LRT island occupied indication to track area highway vehicle detection system controller when LRT track 1 or track 2 island track circuit is occupied.
SP124XOTPR	UPRR island track circuit repeater relay. Used to provide UPRR island occupied indication to track area highway vehicle detection system controller.
124WEGDR	Picked when west exit gate down cam contact is closed. Used to provide west exit gate down indication to track area highway vehicle detection system controller and contact closure for UPRR event recorder.

When first installed, the cameras were used to conduct tests of video-based vehicle detection systems. These tests were done to determine if the use of a non-intrusive video-based vehicle detection system might be feasible for track area vehicle detection. Two products, both considered to be state-of-the-art at the time that the tests were conducted, were installed and tested, Econolite's Autoscope™ and Peek Traffic's VideoTrak 900™.

4.4.6 Rail Operations Center Alarm Points

As already described, a system failure or suspected system failure condition causes the system controller to generate an alarm. Two alarms indications are used, one at a time and in combination for selected conditions as already summarized in Table 4-1. The alarms are displayed on the train control system screens used by the Rail Controllers at the Rail Operations Center, in the same manner as other alarm messages generated in connection with LRT operations.

```
METRO BLUE LINE 124TH STREET GRADE CROSSING
EVENT RECORDER DATA ANALYZER
DATE : 01/09/99
FROM 0:23  TO 23:48
ELAPSED TIME 23:25 HOURS

GATE DOWN CALLS
LRT  : 165     TWO LRTS AT SAME TIME : 12
SB TAIL RINGS : 4      NB TAIL RINGS : 6
AVERAGE SECS LRT APPROACH OCCUPIED  : 33
UPRR : 15      FALSE GATE DOWN CALLS : 1
AVERAGE SECS UPRR APPROACH OCCUPIED : 174

EXIT GATES HELD UP
LRT  : 4    AVERAGE SECS HELD UP : 2
UPRR : 1    AVERAGE SECS HELD UP : 2

EXIT GATES NOT DOWN FOR TRAIN IN CROSSING
LRT  : 1
UPRR : 0
```

```
METRO BLUE LINE 124TH STREET GRADE CROSSING
EVENT RECORDER DATA ANALYZER
GATES HELD UP AND GATES NOT DOWN EVENTS
DATE : 01/09/99
FROM 0:23  TO 23:48

GATES HELD UP WITH LRT TRAIN ON APPROACH
START TIME: 08:04:39.6  END TIME: 08:04:42.6   ELAPSED SECONDS: 3 (LOOP 8)
START TIME: 13:41:39.4  END TIME: 13:41:40.1   ELAPSED SECONDS: 1
START TIME: 14:15:56.9  END TIME: 14:15:58.1   ELAPSED SECONDS: 2
START TIME: 15:28:12.7  END TIME: 15:28:16.4   ELAPSED SECONDS: 4 (LOOP 8 - GATES PUMPED)

GATES HELD UP WITH UPRR TRAIN ON APPROACH
START TIME: 15:39:57.8  END TIME: 15:39:59.3  ELAPSED SECONDS: 2 (LOOP 8)

GATES NOT DOWN FOR LRT TRAIN IN CROSSING
TIME AT CROSSING: 15:28:23.7 (GATES PUMPED - NOT DOWN)

GATES NOT DOWN FOR UPRR TRAIN IN CROSSING
NONE
```

```
METRO BLUE LINE 124TH STREET GRADE CROSSING
EVENT RECORDER DATA ANALYZER
DATE : 01/09/99
FROM 0:23  TO 23:48

GATES HELD DOWN FOR SB LRT TAIL RING AT: 07:57:27.0
GATES HELD DOWN FOR SB LRT TAIL RING AT: 12:02:20.9
GATES HELD DOWN FOR SB LRT TAIL RING AT: 13:56:08.8
GATES HELD DOWN FOR SB LRT TAIL RING AT: 14:39:50.7
UPRR FALSE GATE DOWN CALL AT: 20:07:08.5
```

Figure 4-6
EVENT RECORDER DATA DAILY ANALYSIS REPORTS

5.0 TRAPPED VEHICLE DETECTION SYSTEMS

The most widely used vehicle detection system employs inductive loops and loop detectors to detect vehicles. The inductive loops create an electromagnetic field with a constant inductance. When a vehicles passes over the inductive loop, or through the electromagnetic field, eddy currents are generated in the vehicle ferromagnetic materials, thereby creating an offsetting electromagnetic field and a change in the inductance of the loop. The detector, located in the traffic cabinet, measures this change in inductance as a vehicle. The inductive loop has been used for traffic applications for several decades.

For the 124th Street trial installation of full closure crossing gates, inductive loops were used for the detection of motor vehicles in the track area. As is reported in Chapter 6 of this report, the inductive loops performed well as a trapped vehicle detection system. Importantly, there were no observed instanaces where trapped vehicles were not detected in the track area. There were a number of false vehicle detects that, after a series of adjustments to the loop detectors, occurred once every 8,200 trains. Additional adjustments were made after the completion of the trial installation period that were designed to further reduce the frequency of the false detects.

Non-intrusive vehicle detection systems were considered for this application. Non-intrusive vehicle detection technologies, such as video imaging systems, have proven to be feasible and cost effective alternatives to inductive loops for certain traffic applications, including vehicle detection at signalized intersections and freeway traffic management applications. Under this project, field evaluations of two video-based vehicle detection products were carried out concurrently with the trial installation project.

Inductive loops are not susceptible to non-vehicle detections when installed correctly. However, they are susceptible to failure, due primarily to pavement conditions, environmental conditions, or improper installation. The cost of loop installation or repair is relatively high and requires lane closures and traffic control during construction. For these and other reasons, there has been a significant demand for non-intrusive alternatives to inductive loops that provide accurate and reliable vehicle detection.

Two video-based vehicle detection products, both considered to be state-of-the-art at the time that the field tests were conducted, were installed and tested as part of the project. Tests were conducted to determine if the use of a non-intrusive video-based vehicle detection system would be feasible for trapped vehicle vehicle detection. All tests were performed at the 124th Street crossing of the Metro Blue Line and UPRR Wilmington Branch Line. The two products selected for testing were as follows:

- Autoscope™ distributed in North America by Econolite Traffic Control Products.
- VideoTrak™ 900, developed by David Sarnoff Research Center, and distributed in North America by Peek Traffic.

Test results showed that the Autoscope™ detection algorithms could not reliabily distinguish between gate arm shadows and motor vehicles, despite extensive adjustments by Econolite technical staff. The gate arm shadows resulted in a high number of false vehicle detects.

Test results for the VideoTrak™ 900 system were generally more positive than for the Autoscope™ product. Extensive adjustments to the detection algorithm parameters by the vendor's technical staff were required in order to obtain test results that were judged to be satisfactory. The test results indicated a direction for more detailed investigations of the VideoTrak™ 900 system but no further studies were undertaken under this project.

5.1 TEST APPROACH

Tests were conducted to investigate the performance of two video-based vehicle detection system products for use as a trapped vehicle detection system. The testing was done by the installation of a fully operational vehicle detection system at the 124th Street crossing, including two video cameras mounted at a height of 38 feet on a utility pole in the northeast quadrant of the crossing, and by evaluation of the performance of the system in detecting motor vehicles in the track area. Real time observation of the system operation and comparisons of manual and system-generated traffic counts were used to evaluate each system's ability to detect vehicles in the track area.

5.2 AUTOSCOPE™ PRODUCT TESTING

A complete Autoscope™ system, including Autoscope™ 2004 processor running version 4.02 software, was installed at the 124th Street crossing. The Autoscope™ 2004 processor consists of a special purpose video imaging computer housed in a Model 332 traffic cabinet that receives continuous video images from the two camera units. Based on the hardware configuration and user-specified parameters, the Autoscope™ processor analyzes changes in the video signals to detect vehicles and calculate traffic parameters. The intersection-based processor is able to communicate with a supervisor computer located at the Rail Operations Center using a telephone modem to receive instructions from the supervisor computer and to download vehicle detection data to the supervisor computer.

The video-based vehicle detection system also provided real-time video surveillance of the track area at the Rail Operations Center where the video camera images were transmitted by a microwave communications link. Video surveillance data was used to verify the performance of the vehicle detection system and traffic counts generated by the vehicle detection system. The video data sent to the Rail Operations Center was recorded by a time lapse VCR for a period of 18 consecutive days between April 9 and May 14, 1996. The recorded data was subsequently viewed to collect the actual traffic count data for comparison with the Autoscope™ count data.

For the Autoscope™ tests, non-directional presence loop detectors were set up for vehicle detection, an input detector was assigned for the XR relay signal, and an output detector was assigned for the exit gate control function. Presence detectors were also placed along the LRT and freight tracks to investigate train detection using the Autoscope™ system. Directional presence detectors that detect vehicles in one direction only were also evaluated as a possible approach for vehicle detection without trains being detected as vehicles but this approach proved to be unsuccessful.

Separate count detectors were created for eastbound and westbound traffic. Each count detector is linked to its own station detector. The count data was stored in 60-minute intervals for the tests.

5.2.1 Test Results and Observations

- Autoscope™ can be configured to detect vehicles in the track area. A system consisting of presence detectors for vehicle detection and count detectors was developed for the tests.
- From a comparison of vehicle detects generated by the Autoscope™ system and visual observations of recorded video data, it appears that Autoscope™ is able to detect all the vehicles in the track area and that vehicles in the track area are not missed.

  When compared to actual count data, Autoscope™ generated counts within plus or minus ten percent of the actual counts about half of the time, excluding early morning time periods. During the early morning hours, when traffic volume is extremely low, the Autoscope™ counts could be off by fifty percent or more with as little as one extra vehicle count. During the time periods where the gate arms cast shadows across the count detectors, the count data could be off by more than twenty percent.

  It was observed that Autoscope™ was not consistent at counting vehicles. Autoscope™ counts could be within 0 or 1 percent of the actual vehicle count for one time period and then off by ten percent or more the next time period. As mentioned earlier, the position of the image sensors probably is a key factor in these highly inconsistent traffic counts.

- Test results indicated a significant problem with false vehicle detects due to gate arm shadows that was not able to be resolved. During the morning and evening hours, the entrance gate arms create long, moving shadows across the track area as they are lowered and raised. These shadows were detected by Autoscope™ as motor vehicles. It is likely that shadows created by the exit gate movements would cause the same type of false vehicle detects. Autoscope™ does have shadow processing capabilities but they were not effective for eliminating the false vehicle detects caused by the gate arm shadows.
- Test results indicate that train detections from the vehicle detectors could not be eliminated but that trains could be detected independently as they entered the track area. The presence detectors set up to detect vehicles in the track area were unable to differentiate between vehicles and trains moving through the track area. To resolve this problem, detectors for the trains only were positioned just outside the normal travel of vehicles. This created a set of train detectors that could detect trains independently of vehicles.
- Test results indicated that false vehicle detects from pedestrians and debris could not be eliminated. The number of false vehicle detects from pedestrians and debris was low, typically between five and ten per day.
- The placement of the camera has a direct effect on the accuracy of vehicle detection for count data. The camera is mounted on a pole thirty-eight feet above the grade crossing on the northeast side of the track area. Since the camera is located to the side of the track area, it is difficult to position an eastbound count detector that will not also count some of the westbound traffic. Westbound vehicles that drive down the middle of the road, or especially tall vehicles, will energize both the westbound and eastbound count detectors. It is possible that mounting the camera higher would reduce the number of redundant counts.
- Autoscope™ does not have the capabilities to perform self checks to insure that the camera and controller units are operating properly. Further research is needed to determine if off the shelf technologies could be integrated into the system to continuously monitor the Autoscope™ system.

- Autoscope™ does provide effective video surveillance of the track area. The video surveillance is useful for project evaluation data collection and will assist train control personnel in responding to problems, if any, with the operation of the full closure crossing gate system.

From the test results, it was determined that the Autoscope™ product as available at the time that the tests were conducted and as configured for the tests was not a feasible alternative for trapped vehicle detection. While Autoscope™ was effective at detecting motor vehicles, Autoscope™ consistently generated an unacceptable number of false vehicle detects from gate arm shadows, pedestrians, and blowing debris.

5.3 VIDEOTRAK™ 900 PRODUCT TESTING

The tests conducted on the VideoTrak™ 900 system were similar to those carried out for the Autoscope™ system. Both qualitative and quantitative analysis of the system performance were done. The qualitative analysis involved observing how well VideoTrak™ 900 detected vehicles and the frequency of false vehicle detects. The quantitative analysis involved collecting VideoTrak™ 900 generated traffic volume counts and comparing them to the actual volume counts determined from video data recording.

The test procedure included creating detector layouts, observing how well vehicles were detected, and if the system produced false vehicle detects. As testing continued, the detector layouts were modified to provide the most comprehensive coverage of the track area. This procedure was continued until it appeared that no more could be done to improve the accuracy of the system.

Figure 5-1 illustrates the detector layout that appeared to provide the most comprehensive coverage of the track area. The detector layout contains three non-directional tracking strips, each containing several detection zones. The three tracking strips (S1, S2, and S3) are outlined in red and are used to track the vehicles through the grade crossing. The detection zones (Z1, Z2, . . ., and Z10) are solid rectangles closely spaced within the tracking strips. A detection zone, when viewed at the supervisor computer, turns green when there is a vehicle detect.

A motor vehicle being driven through the track area will pass through at least one of the tracking strips. If the vehicle meets the tracking strip attributes, the corresponding detection zones will be energized when the vehicle passes through them. The use of tracking strips with detection zones is intended to eliminate false vehicle detects.

Initial testing was completed using the default algorithm parameter settings. Using the default settings, VideoTrak™ 900 appeared to detect every vehicle passing through the grade crossing but VideoTrak™ 900 also produced numerous false vehicle detections, primarily due to shadows. The initial tests concluded that VideoTrak™ 900 was not able to meet the minimum requirements of a trapped vehicle detection system.

Discussions with Peek Traffic technical staff concerning the false vehicle detects revealed that VideoTrak™ 900 allows the user to change certain algorithm parameters in order to modify the VideoTrak™ 900 vehicle detection data processing. With the technical assistance provided by Peek Traffic technical staff, changes were made to selected parameters, including the following changes:

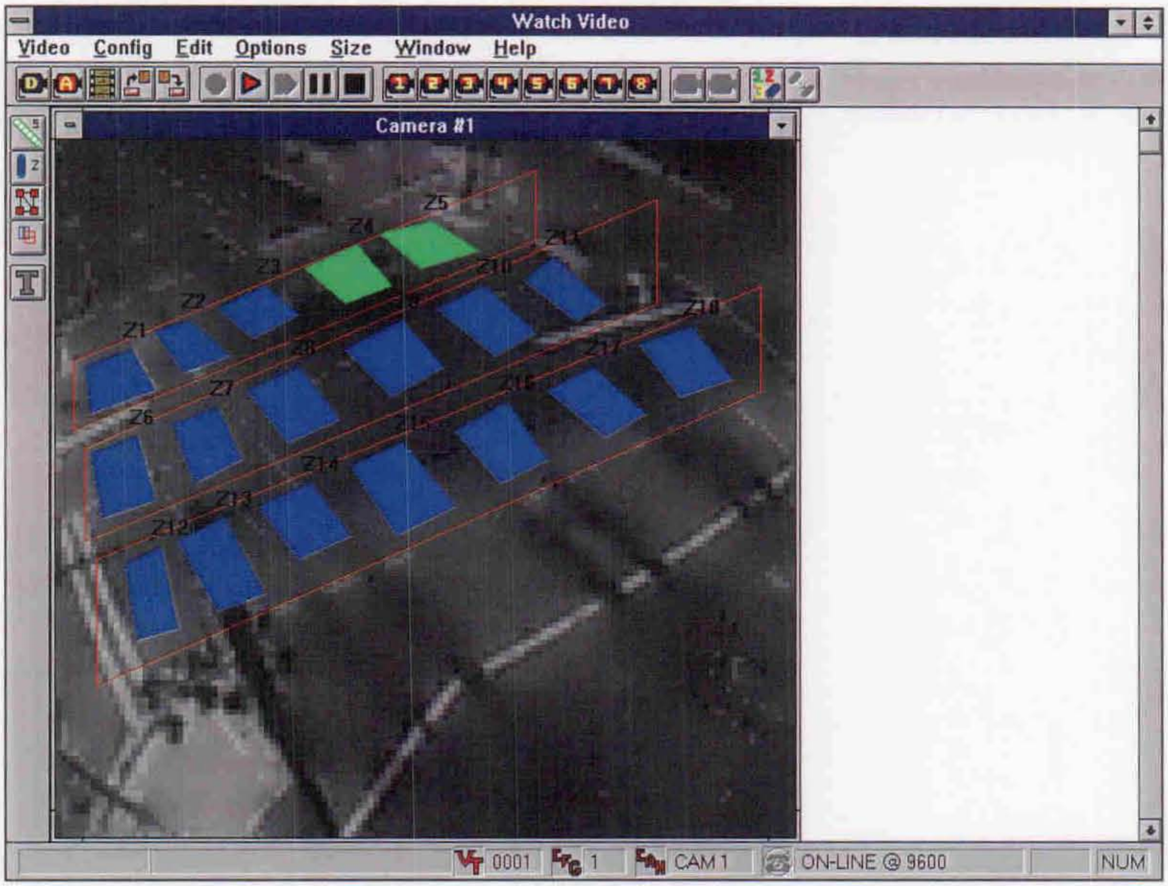

Figure 5-1
VIDEOTRAK™ TEST DETECTION STRIPS AND ZONES

- minimum size of detectable objects;
- speed with which objects must move to be detected; and
- the recycle time for updating the background.

Tests were performed after the changes were made to the algorithm parameters. The tests showed that the false vehicle detects, with the exception of LRT and UPRR freight trains, were eliminated without noticeable changes to vehicle detection. Train detects are acceptable as false vehicle detects because trains can be detected using other methods and thereby eliminated as vehicle detects.

The tests conducted with the revised algorithm parameters also showed occasional missed detection of dark-colored vehicles. Given the fact that this problem was not observed prior to changing the algorithm parameters, further parameter changes may be required to remedy this problem without reintroducing unacceptable number of false vehicle detects. Further parameter changes were not tested as part of the project.

5.3.1 Test Results and Observations

Tests results indicate that VideoTrak™ 900 is a feasible alternative to inductive loops as a trapped vehicle detection system. Observations demonstrated that the VideoTrak™ 900 product is able to accurately detect vehicles, except for certain dark-colored vehicles under certain circumstances, without producing false vehicle detects. Further study of algorithm adjustments to eliminate the missed detects as well as an in-depth review of the system's failure modes would be required before the product is deployed at a grade crossing for trapped vehicle detection.

The test observations and findings are summarized below.

- VideoTrak™ 900 can be configured as a video imaging vehicle intrusion detection system. A detector system integrating presence detection and vehicle count data can be developed. VideoTrak™ 900 is easy to learn and loop configurations can be easily modified. Specialized training appears to be required to tune the detection algorithms.

- Physical observation is the only way to verify VideoTrak™ 900 performance, which limits the ability to make definitive conclusions about VideoTrak™ 900 accuracy. No method exists of creating a data base that records individual detector zone detections.

- Prior to changing the detection algorithm parameters, it appeared that VideoTrak™ 900 detected every vehicle passing through the field of view. Tests performed after the detection parameter changes required to eliminate false vehicle detects revealed that dark-colored vehicles were occasionally missed by some but usually not all the detectors that should have detected the vehicle.

- Tests of the VideoTrak™ 900 volume count capabilities revealed that there are several problems related to collecting volume data, but these problems do not effect vehicle detection. VideoTrak™ 900 volume data was inconsistent and typically higher than actual volume counts. Several factors are responsible for the inaccurate volume count data, including the detection of trains and multiple detections per vehicle. First, since trains are detected as vehicles, they contribute to the volume counts, creating higher vehicle counts. Second, VideoTrak™ 900 detector zones occasionally counted one vehicle as two separate detects, resulting in two or more counts for one vehicle. This problem was also observed for train detections, where one train is counted multiple times. These two factors have a cumulative effect on volume counts, but do not hinder the vehicle presence detection capabilities.

- VideoTrak™ 900 was not observed to be susceptible to false vehicle detects due to shadows, debris, or the moving gate arms. It was observed that VideoTrak™ 900 occasionally detected pedestrians walking in the traffic lanes and bicyclists as vehicle detects.

- VideoTrak™ 900 appears to be directly affected by the placement of the cameras. The position of the cameras results in the vehicles crossing the field of view at an angle that is nearly 45 degrees. According to Peek Traffic technical support, this angle of view limits the capabilities of the tracking zones. At a 45 degree angle, the tracking zones have difficulty differentiating between horizontal and vertical movement. Future testing of the VideoTrak™ 900 product should include rotating the camera or alternative camera unit placements.

- VideoTrak™ 900 is capable of performing self checks to insure that the camera and processor units are operating properly. When a detection zone has failed or the camera field of view is significantly degraded or lost, VideoTrak™ 900 enters a fail safe mode of operation. For a trapped vehicle detection system, the fail safe mode would result in "always on" vehicle detection outputs.

- VideoTrak™ 900 does provide effective video surveillance of the track area. The video surveillance was useful for project evaluation data collection and, if deployed for trapped vehicle detection, will assist train control personnel in responding to problems.

The VideoTrak™ 900 product appears to meet the accuracy requirements of a trapped vehicle detection system. Tests indicate that VideoTrak™ 900 is able to detect nearly all the vehicles that pass through the track area. No vehicles were observed going completely undetected, but dark-colored vehicles were occasionally not detected by some of the detection zones. Further fine tuning of the algorithm parameters may be able to resolve this problem without jeopardizing the capability to not create false vehicle detections.

6.0 TRIAL INSTALLATION RESULTS

Under this project, video and event recorder data was collected and analyzed to meaure the effectiveness of the full closure crossing gate system at the 124th Street crossing of the LACMTA Metro Blue Line and UPRR Wilmington Branch in the County of Los Angeles. The data was collected for a period of 180 consecutive days from October 20, 1998 through April 30, 1999. During the evaluation time period, the full closure crossing gate system operated for nearly 41,000 gate down calls as follows:

- 36,751 gate down calls (average 204 per day) by Metro Blue Line LRT trains;
- 2,766 gate down calls (average 15 per day) by UPRR freight trains; and
- 1,266 false gate down calls (average seven per day) initiated by UPRR grade crossing predictor equipment.

6.1 HIGHWAY VEHICLE DETECTS

The track area highway vehicle detection system caused the exit gates to be held up, or to be returned to their vertical position, as the result of a vehicle detect in the track area as follows.

- The exit gates were held up 1,119 times, or about once every 36 trains on the average, during the trial installation period as the result of a motor vehicle being detected in the track area. The exit gates were held up more frequently for UPRR freight trains, about once every 22 trains on the average, than for LRT trains (see Figure 6-1).
- On the average, the exit gates were held up two seconds each time that they were held up. The exit gates were held up 76 times for five seconds or longer; the exit gates were held up 12 times for nine seconds or longer (see Figure 6-2). When the gates were held up for five seconds or longer, this was primarily due to motorists on the tracks when the gates started down waiting to exit from the track area or, secondly, to motorists who backed out from under one of the entrance gates. Figure 6-3 summarizes the reasons for the exit gates being held up for longer than five seconds.
- The exit gates were not down when an LRT train entered the island track circuit, as the result of being held up or pumped for a highway vehicle detect, a total of ten times or an average of once every 3,679 trains.
- The exit gates were held up 12 times for nine seconds or longer as the result of a highway vehicle being detected, 11 times for LRT gate down calls and one time for a UPRR gate down call. These instances were recorded as follows: one time for a motorist backing out from under the east entrance gate as it was being lowered; four times for a motorist backing out from under the west entrance gate as it was being lowered; two times as the result of the tail of an eastbound vehicle stopped and waiting to exit from the track area being detected; and four times caused by the tail of a westbound vehicle stopped and waiting to exit from the track area being detected.

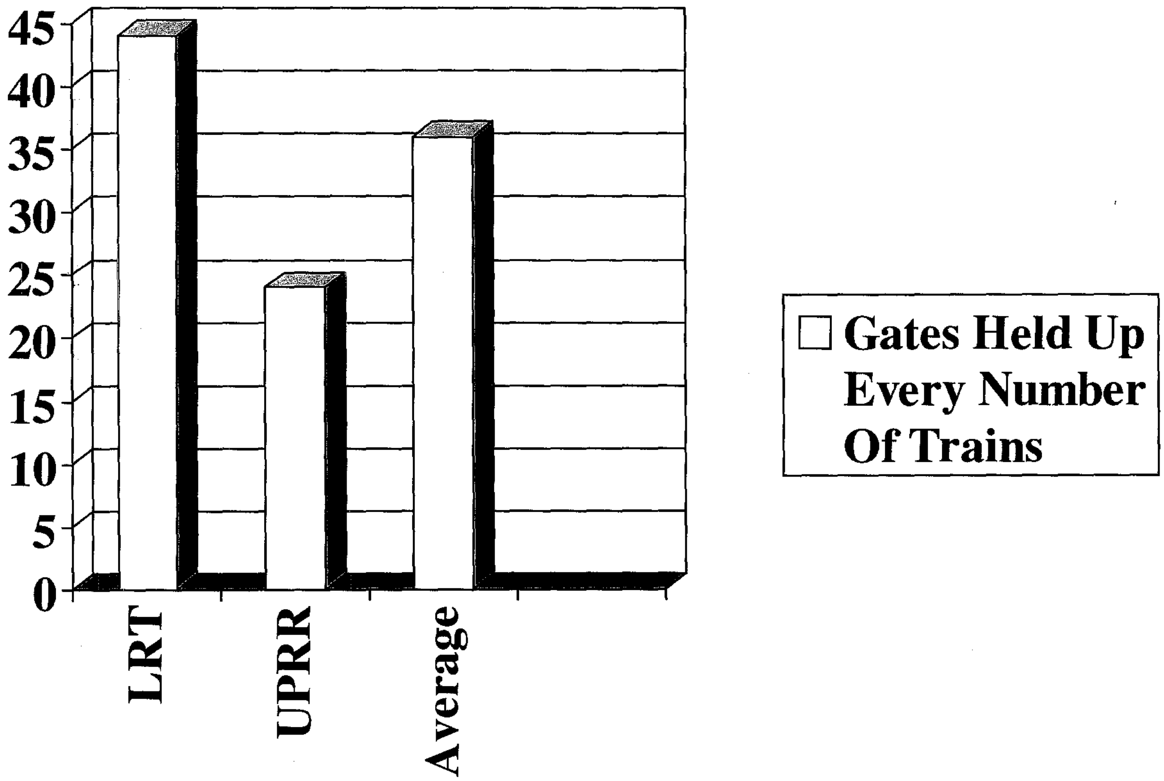

Figure 6-1
FREQUENCY OF EXIT GATES BEING HELD UP

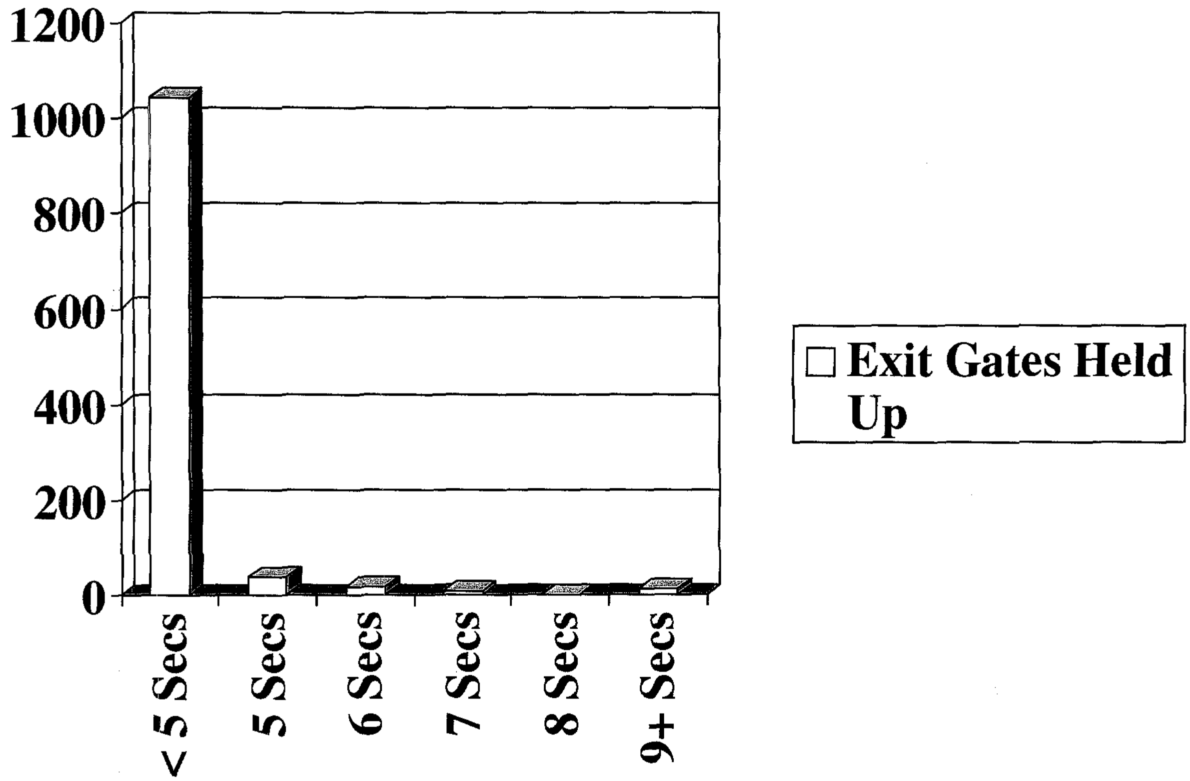

Figure 6-2
NUMBER OF SECONDS EXIT GATES HELD UP

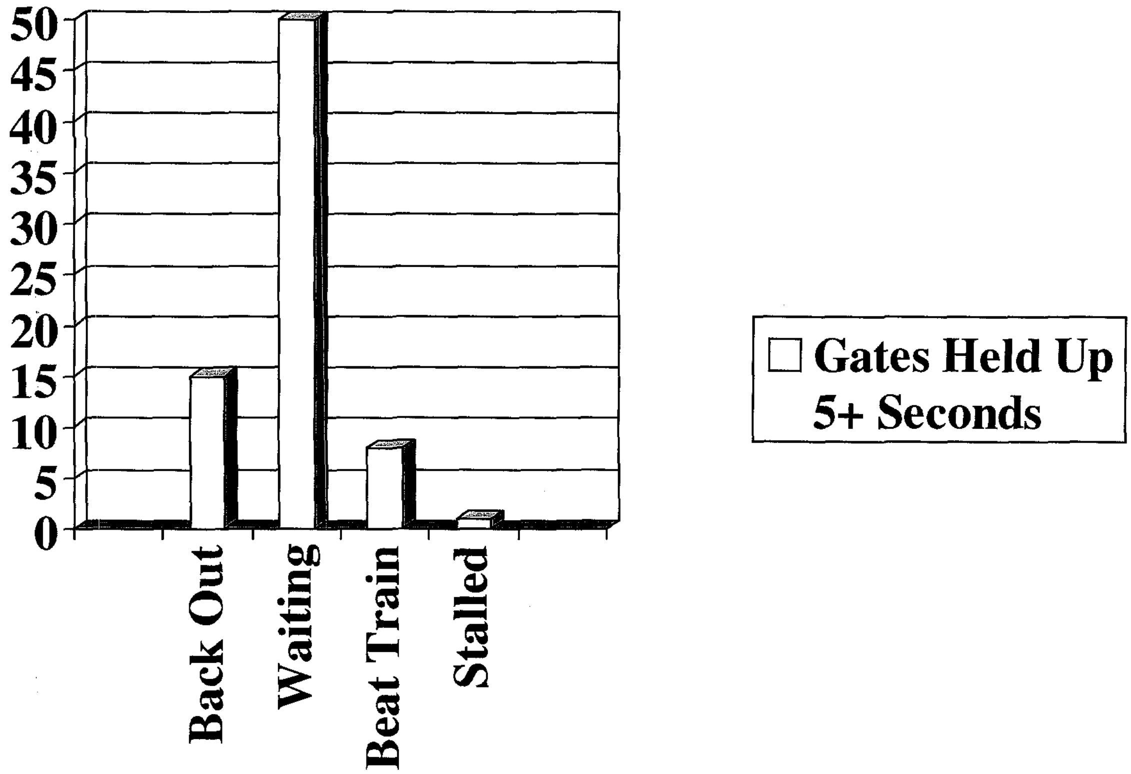

Figure 6-3
REASON FOR GATES BEING HELD UP MORE THAN FIVE SECONDS

- The exit gates were pumped, as the result of a highway vehicle being detected in the track area after the exit gates had started down, only seven times. In all seven instances, the gates were being called down by an LRT train. This is equivalent to one time every 5,857 trains on the average. The exit gates were never pumped more than one time as the result of any vehicle detect.

6.2 FAILURE TO DETECT HIGHWAY VEHICLES

No instance has been observed in the field, observed on video tape recordings, or otherwise reported where a highway vehicle in the track area has not been detected.

6.3 ABNORMAL RAILROAD EQUIPMENT OPERATIONS

The full closure crossing gate system has operated as designed for the following instances where the railroad equipment has operated in an abnormal manner. Under these circumstances, the exit gates as well as the track area highway vehicle detection system has continued to function normally or, in one case, shut itself down and generated an alarm indicating that it was shut down.

- 1,266 false gate down calls (average seven per day) initiated by UPRR grade crossing predictor equipment. Under this condition, the exit gates start down normally and, if not timed out, will be fully lowered until the XR relay is released.

- 1,015 tail rings (average five per day) after southbound LRT trains have cleared through the crossing, resulting in the gates being held down for as long as a minute after the LRT train has cleared the island circuit. Under this condition, the exit gates remain down until the XR relay is released.

- 2,278 tail rings (average 12 per day) after northbound LRT trains have cleared through the crossing, resulting in the gates being held down for at least 20 seconds after the LRT train has cleared the island circuit. Under this condition, the exit gates remain down until the XR relay is released.

- The four quadrant gates were taken out of service for seven days in February (early morning on 02/12/99 through early morning on 02/19/99) as the result of a failure of the UPRR grade crossing predictor primary unit. The failure of the primary unit resulted in the control of the crossing being switched to the backup predictor unit which, at the time of the failure, was not connected to the repeater relay providing the UPRR island circuit occupied indication required for the operation of the track area highway vehicle detection system. This condition resulted in a constant back contact closure, indicating that the UPRR island circuit was constantly occupied, and in the track area vehicle detection system properly shutting itself down and causing the exit gates to be held in the up position. This condition did not affect the operation of the entrance gate equipment in any way.

6.4 FALSE HIGHWAY VEHICLE DETECTS

During the 180 days, there were a total of 38 false highway vehicle detects that resulted in the exit gates being pumped or being held up without being lowered at all.

Shortly after the full closure gate system was placed into operation on October 20, a number of false highway vehicle detects were observed. The false highway vehicle detects resulted in the exit gates being held up for a few seconds or for the full time that the approach track circuit was occupied; in the exit gates being pumped often just before an LRT train entered the island; and, for instances where the exit gates were not down for three trains in a row (this condition is alarmed as a means to identify broken gate arms where the gate arm continuity circuit has been broken), in the system shutting itself down and causing the exit gates to be held in the up position until the system controller was manually reset.

Thirty-five of the false highway vehicle detects were observed in the ten weeks before December 22. After the three loop detector adjustments were made, three false detects were observed in the 17 weeks from December 22, 1998 to April 30, 1999. This is equivalent to one false highway vehicle detect every 8,200 trains on the average.

6.5 TRAIN DETECTS

The exit gates were raised, after being down, 47 times as the result of trains or hi-rail maintenance vehicles being detected by the track area loops. This occurred 28 times between October 20 and December 22, and another 19 times after December 22, 1998.

The following types of train detects were observed during the trial installation period.

6.5.1 LRT Vehicle Detected In Crossing

The exit gates start up as the LRT train is detected in the track area, before the island circuit occupancy indication is received and acted upon by the track area vehicle detection system controller. False detects of this type were observed 26 times prior to December 22, 1998 including 22 times for southbound LRT trains, three times for northbound LRT trains, and one time for a reverse running LRT train on the normally northbound track. After December 22, these false detects were observed seven times, six times for northbound LRT trains and one time for a reverse running southbound LRT train. Note that no false detects of this type were observed for normal running southbound LRT trains after December 22 when the third of three loop detector adjustments were made. Also note that no loop detector adjustments were made to eliminate the false vehicle detects by northbound LRT trains and that the frequency of these false detects remained about the same for the full duration of the trial installation, at about one time every three weeks.

The addition of logic that causes the exit gates to be held down when they are down would fully eliminate the effect of these false detects. In addition, it should be possible to eliminate these false detects by increasing the time delay, by one or two tenths of a second, for acting on track area vehicle detects in order to allow more time for the island circuit occupied indication to be received.

6.5.2 UPRR Freight Train Detected in Crossing

This was observed one time for a duration of seven seconds in the middle section of a long freight train. The addition of logic that causes the exit gates to be held down when they are down would eliminate the effect of this type of false detect.

6.5.3 Hi-Rail Vehicle Not Shunting Island Track Circuit

These train detects caused the exit gates to be raised as the result of a hi-rail vehicle being detected by the track area vehicle detection loops without generating an island circuit occupied indication. False vehicle detects of this type occurred 12 times for UPRR hi-rail vehicles, four times when the gates were down for LRT trains and eight times when the gates were down for the hi-rail vehicles. One instance was observed where a reverse running LACMTA hi-rail maintenance vehicle did not shunt the island circuit.

6.6 TRAPPED HIGHWAY VEHICLES

No instance was observed in the field, observed on video tape recordings, or otherwise reported where a highway vehicle has been trapped in the track area behind the lowered crossing gates.

6.7 REDUCTION IN S-TURNS AROUND LOWERED CROSSING GATES

Data recorded for the trial installation period shows that the approach is working to deter motorists from driving around the lowered crossing gates.

Data collected before the system was installed showed that motorists drove around the lowered gates, taking the risk of being hit by a train, about three times every five days on the average.

Over a period of 180 days, motorists would drive around the lowered crossing gates a total of 108 times. Since the installation of the additional crossing gates, motorists have driven around the lowered gates, under one of the additional crossing gates or exit gates as they are being lowered, a total of seven times and, after the additional crossing gates are already down, no times. With the system in place, motorists have been observed driving around or under the lowered gates about once every 26 days on the average or a substantial 94 percent reduction in the number of risky s-turn moves by motorists using the intersection.

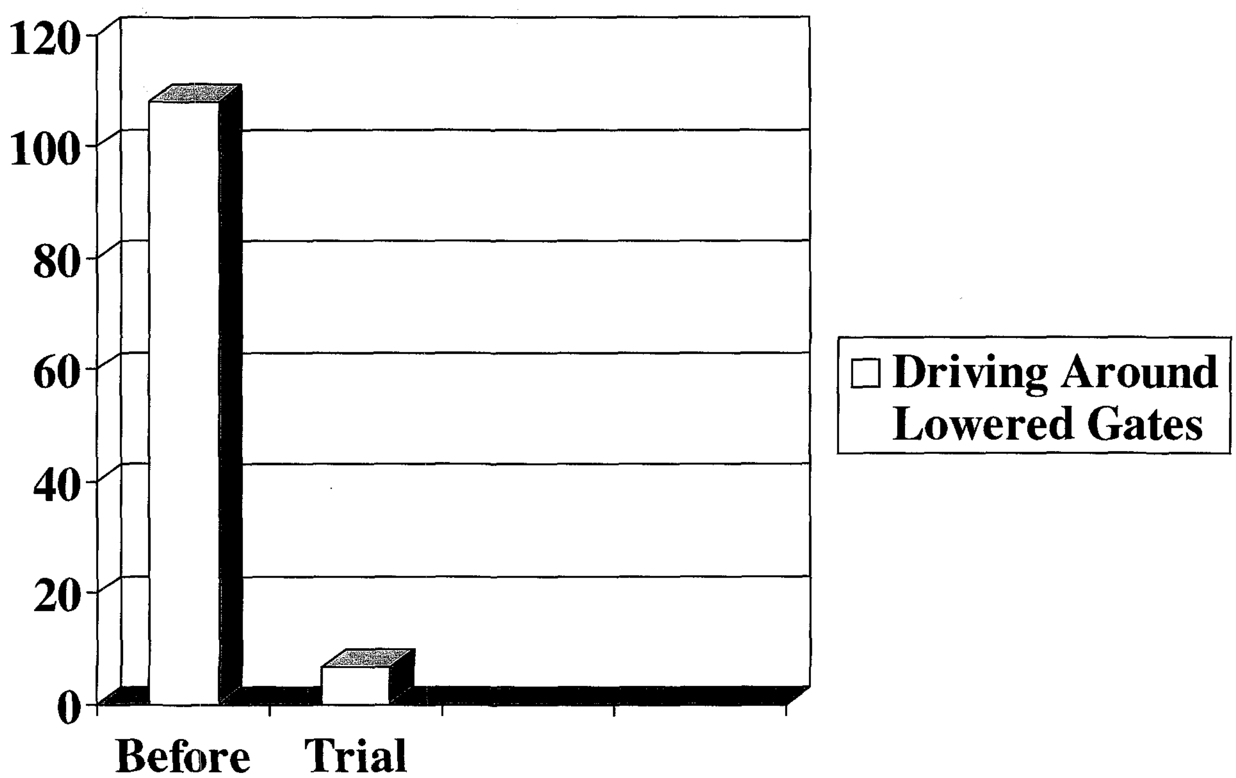

Figure 6-4
REDUCTION IN S TURNS AROUND LOWERED CROSSING GATES

6.8 STALLED MOTOR VEHICLES IN TRACK AREA

There was one instance of a stalled motor vehicle in the track area where the exit gates were held up for five seconds while the motorist pushed his vehicle out of the track area.

6.9 NUISANCE FALSE DETECTS

The use of inductive loops for track area vehicle detection could be subject to "nuisance" false detects, resulting from objects with the required ferromagnetic properties being placed on or inadvertently falling on one of the track area vehicle detection loops. For example during the system testing, a highway warning sign was used to simulate the presence of a motor vehicle in the track area for certain tests. No nuisance detects were observed during the trial installation period.

6.10 SYSTEM FAILURES AND TIME TO REPAIR

There have been no failures in any of the equipment required for the operation of the exit gates and track area vehicle detection system to date, except that it was necessary to replace one of the exit gate arm lamp circuit connectors.

A power supply transformer for the video microwave transmitter also failed and was replaced.

There have been no entrance or exit gate arms broken, either as the result of a motorist driving into one of the gate arms or as the result of an exit gate arm striking a vehicle waiting to exit from the track area. There have been a few instances observed where the entrance gates have struck or nearly struck the front end of a vehicle stopped too close to the track area.

6.11 FINDINGS AND RECOMMENDATIONS FOR PERMANENT INSTALLATION

There are five principal findings and recommendations related to the trial installation results and permanent operation of the full closure crossing gates at the 124th Street grade crossing.

Data recorded for the trial installation period shows that the approach is working to deter motorists from driving into the track area after the entrance gates are down. Furthermore, the system equipment, including the exit gate mechanisms modified to fail safe in the up position, has functioned for the trial installation period without any mechanical or operational problems that would prevent the system from being put into permanent operation.

Data collected before the system was installed showed that motorists drove around the lowered gates, taking the risk of being hit by train, about three times every five days on the average. Since the installation of the additional crossing gates, motorists have driven around the lowered gates, under one of the additional crossing gates or exit gates as they are being lowered, a total of seven times and, after the additional crossing gates are already down, no times. With the system in place, motorists have been observed driving around or under the lowered gates about once every 26 days on the average or a significant 94 percent reduction in the number of risky moves by motorists using the intersection.

Is trapped highway vehicle detection needed? Would a motorist have been trapped in the track area without trapped vehicle detection? It is not possible to say for sure. Out of the 41,000 gate down calls and eleven hundred and nineteen times that the exit gates were held up, 13 instances can be identified where a motorist might have been trapped, depending on how the motorist would have reacted to the exit gate being lowered in front of him or her. If one or two of these 13 instances resulted in a motorist being trapped, then the track area vehicle detection system was clearly warranted.

The 13 instances where motorists might have been trapped in the track area included eight instances where motorists were trying to beat trains and causing the exit gates to be held up for more than five seconds; four instances occurred when the exit gates were pumped from an angle of about 45 degrees and were not down when the train entered the crossing; and one instance involved a stalled vehicle that was pushed off the tracks. Figure 6-5 provides a summary of the 13 instances where motorists might have been trapped on the tracks.

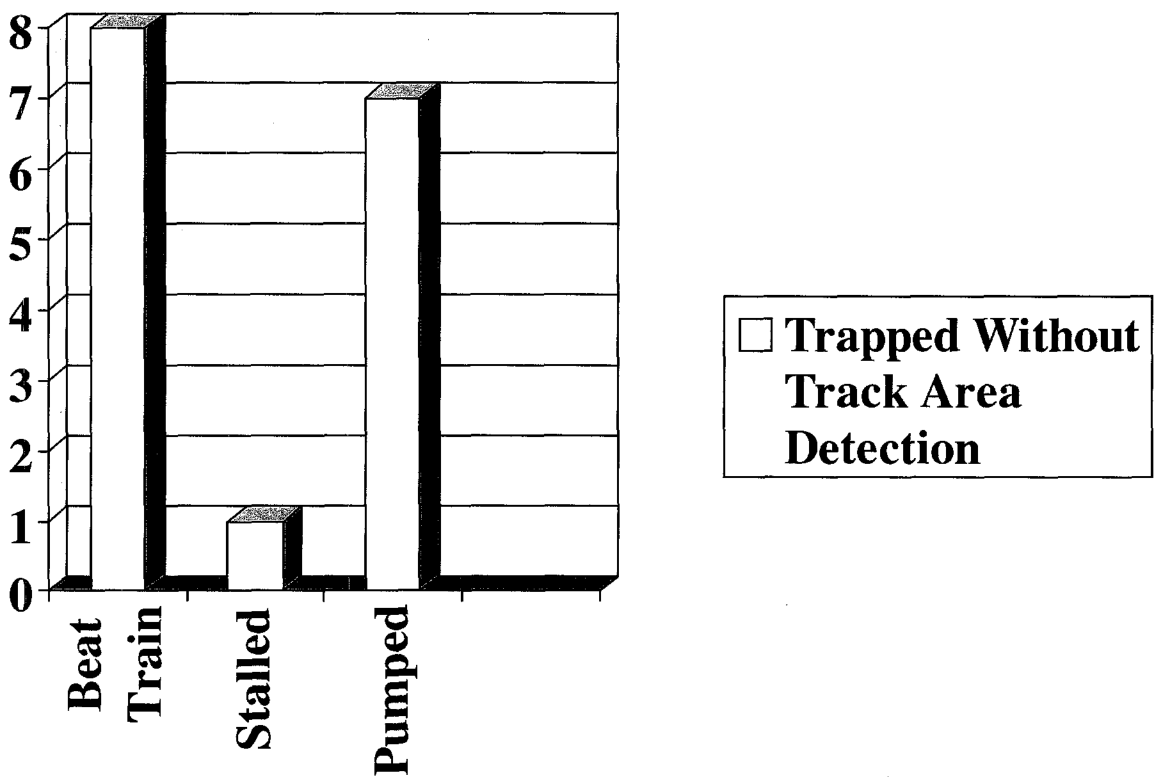

Figure 6-5
TRAPPED MOTORISTS WITHOUT TRACK AREA DETECTION

The trapped vehicle detection loops have worked well with one significant problem area that was addressed during the trial installation period and then again with one recommended change prior to the cutover to permanent operation. Shortly after the start of unattended operation, it was observed that the operation of the vehicle detection loops was being affected, from time to time, by the traction power return currents in the southbound LRT rails. Three adjustments were made in the frequency and sensitivity settings for the detectors, and after the third of these adjustments was made, the problem was observed only three times during the trial installation period, an average of once every 8,200 trains on the average. For two times of the three times, the problem was barely noticeable.

A total of 38 false highway vehicle detects were recorded during the trial installation period, 35 in the weeks before December 22 and three after that date when the third of three loop detector adjustments were made. The false vehicle detects were of two general types – first, short duration typically only a few seconds; and second, long duration extending for at least 20 seconds to as long as several minutes. The loop detector adjustments served to reduce the frequency of short duration false highway vehicle detect to one every 12,300 trains and the frequency of long duration false highway vehicle detects to one every 24,600 trains

For each of the three false highway vehicle detects that were recorded between December 22 and April 30, 1998, the system operated safely with the exit gates being held up as a result of the false vehicle detect. For the two short duration false highway vehicle detects, the effect of the false detects would have been barely noticeable, if at all, to motorists. For the one long duration false highway vehicle detect, the exit gates were held up for three trains in a row as a result of the false vehicle detect which, in turn, caused the system controller to shut itself down and the exit gates to remain in the up position until the system controller was manually reset.

However, having noted that the system is failing in a safe manner from the point of view of possibly trapping a motorist in the track area, it is recognized that holding the exit gates up in this manner is not as safe as it could be for motorists using the crossing, in the same way that false gate down calls and tail rings at crossings equipped with entrance gates only provide a confusing message for motorists. In comparison with the number of false gate down calls and tail rings experienced at the crossing, the number of false highway vehicle detects has been very small.

From observation of the loop detectors, the false highway vehicle detects are believed to be caused by intermittent crosstalk between one or more of the vehicle detection loops and electromagnetic fields being generated by elements of the LRT traction power return current in the normally southbound LRT rails.

As already noted, loop detector adjustments have served to reduce the frequency of false highway vehicle detects to about one false highway vehicle detect about every 8,200 gate down calls. It is believed that the current performance is acceptable for permanent operation of the trapped highway vehicle detection system.

The exit gates were raised, after being driven down, 47 times during the trial installation period as the result of trains or hi-rail maintenance vehicles being detected by the track area loops. This occurred 28 times in the weeks before December 22, 1998 and another 19 times after December 22, 1998 when the third of three loop detector adjustments were made.

The train detects, causing the exit gates to be raised from their lowered position, recorded after December 22, 1998 were of four types – first, seven times for LRT trains on the normally northbound LRT track 1; second, one time for a duration of seven seconds in the middle section of a long UPRR freight train; third, 10 times as the result of UPRR hi-rail maintenance vehicles not shunting the island track circuit; and fourth, one time for a reverse running LACMTA hi-rail maintenance vehicle.

Certain changes need to be implemented, before permanent operation is commenced, to prevent the exit gates from being raised when trains and hi-rail maintenance vehicles are detected as highway vehicles in the crossing. This situation is not especially hazardous if there is only one train or hi-rail vehicle in the crossing, as the exit gates are raised as the train or high-rail vehicle is occupying the crossing, but is very dangerous if there are two trains or a train and hi-rail vehicle in the crossing at the same time.

Two changes are needed in connection with the operation of the exit gates at the 124th Street crossing before permanent operation is commenced. Both changes are required to eliminate the exit gates being raised by train detects. First, the addition of logic that causes the exit gates to be held down when they are down would eliminate the effect of all train detects, except for instances where hi-rail maintenance vehicles enter the crossing before the exit gates are down. Second and to accommodate those instances where hi-rail vehicles do not wait until the exit gates are down, the operating procedures for UPRR and LACMTA hi-rail maintenance vehicles should be reviewed to ensure that the vehicles are directed to wait until all the crossing gates are down before entering the crossing.

Table 6-1 provides a summary of the types and number of false highway vehicle detects and train detects experienced during the trial installation period.

Also shown in the table are the changes that could be implemented to mitigate the effect of the false highway vehicle detects and trains detects, and the changes that are recommended to be done before operation is commenced.

The trapped vehicle detection system logic implemented at the 124th Street crossing allows for a vehicle detect to be acted on after the exit gates are down (only for six out of the eight track area loops, and not for the loops adjacent to the gates on the east side of the crossing due to their proximity to the gates). The logic was implemented in this manner based on direction from the LACMTA to minimize the possibility of a motorist being trapped in the track area. It is recommended that this logic will be revised for the permanent installation of the trapped vehicle detection system at the crossing.

There has been a problem during the trial installation period with UPRR hi-rail vehicles not shunting the island circuit and being detected as highway vehicles, causing the exit gates to pump. This is not especially troublesome unless there is a LRT train approaching the crossing at the same time, at which time it is a hazardous condition. It should be possible to resolve this problem area by working with the UPRR to implement an operating procedures that requires the hi-rail vehicle to wait until all gates are down before entering the crossing. It is also recommended that the operating procedures for UPRR and LACMTA hi-rail maintenance vehicles be reviewed and revised, as necessary, to ensure that the hi-rail vehicles are directed to wait until all the crossing gates are down before entering the crossing.

The modified exit gate mechanisms have worked without any problems. Broken gate arm detection with the modified gate mechanism needs to be improved. At 124th Street, the continuity of the gate arm lamp circuits as well as logic based on the gates being held up with a train occupying the island circuit for three consecutive trains has been used but both approaches have problems.

Table 6-1
RECOMMENDED MITIGATIONS TO MINIMIZE FALSE VEHICLE DETECTS FOR PERMANENT OPERATION

False Highway Vehicle or Train Detect Type	Believed Cause	Level of Risk	Number Before 12/22/98	Number After 12/22/98	Freq After 12/22/98	Possible Additional Mitigations	Recommended Additional Mitigations For Permanent Operation
Short Duration False Highway Vehicle Detect After Exit Gates Down	Crosstalk between vehicle detection loops and track-based loop circuit carrying traction power return currents.	High	9	0	n/a	1. Install insulated joint with impedance bond on southbound LRT island circuit boundary. 2. Use loop detectors that provide different or wider range of operating frequencies. 3. Implement logic to hold exit gates down when exit gates are down.	Implement controller logic to hold exit gates down when exit gates are down.
Short Duration False Highway Vehicle Detect Before Exit Gates Down, Causing Exit Gates To Pump	Crosstalk between vehicle detection loops and track-based loop circuit carrying traction power return currents.	High	12	0	n/a	1. Install insulated joint with impedance bond on southbound LRT island circuit boundary. 2. Use loop detectors that provide different or wider range of operating frequencies	None.
Short Duration Highway Vehicle Detect Before Exit Gates Start Down	Crosstalk between vehicle detection loops and track-based loop circuit carrying traction power return currents.	Low	2	2	12,300	1. Install insulated joint with impedance bond on southbound LRT island circuit boundary. 2. Use loop detectors that provide different or wider range of operating frequencies	None.
Long Duration False Highway Vehicle Detects	Crosstalk between vehicle detection loops and track-based loop circuit carrying traction power return currents.	Low To Medium	12	1	24,600	1. Install insulated joint with impedance bond on southbound LRT island circuit boundary. 2. Use loop detectors that provide different or wider range of operating frequencies.	None.
LRT Train On Track 1 (Normally Northbound) Detected In Crossing	Island circuit occupied indication not being delivered in advance of LRT train being detected.	Low; High For Two Trains At Same Time	3	7	3,510	1. Implement logic to hold exit gates down when exit gates are down. 2. Increase highway vehicle detect recognition delay to greater than 1.0 seconds.	Implement controller logic to hold exit gates down when exit gates are down.
LRT Train On Track 2 (Normally Southbound) Detected In Crossing	Island circuit occupied indication not being delivered in advance of LRT train being detected.	Low; High For Two Trains At Same Time	23	0	n/a	1. Implement logic to hold exit gates down when exit gates are down. 2. Increase highway vehicle detect recognition delay to greater than 1.0 seconds.	None.
UPRR Freight Train Detected in Crossing	Not known.	Low	0	1	24,600	1. Implement controller logic to hold exit gates down when exit gates are down.	Implement controller logic to hold exit gates down when exit gates are down.
Hi-Rail Vehicle Not Shunting Island Track Circuit		Low; High For Two Trains At Same Time	2	11	2,240	1. Implement operating procedure to ensure that all gates are down before hi-rail vehicle proceeds into crossing. 2. Implement operating procedure to ensure that vehicle does not proceed through crossing when LRT trains are in the vicinity.	Implement operating procedure to ensure that all gates are down before proceeding (together with controller logic to hold exit gates down when exit gates are down).

6.12 FOLLOWUP OPERATIONS REVIEW

Both of the recommended mitigations were implemented at the 124th Street crossing. Video and event recorder data was collected for a period of 25 consecutive days from March 15 through April 8, 2002 to confirm that the changes had been properly implemented and to determine if any significant changes in motorist behavior or system performance could be observed.

During this followup data collection period, the full closure crossing gate system operated for approximately 4,700 gate down calls as follows:

- 4,305 gate down calls by Metro Blue Line LRT trains;
- 398 gate down calls by UPRR freight trains; and
- 142 false gate down calls initiated by UPRR grade crossing predictor equipment.

6.12.1 Highway Vehicle Detects

The trapped vehicle detection system caused the exit gates to be held up, or to be returned to their vertical position, as the result of a vehicle detect in the track area as follows.

- The exit gates were held up 224 times for LRT trains, as the result of a motor vehicle being detected in the track area. This is equivalent to once every 19 trains on the average, about twice as often as measured during the trial installation period. For UPRR trains, the exit gates were held up 42 times or about once every nine trains, also about twice as often as observed for the trial installation period.

- On the average, the exit gates were held up only one second each time that they were held up.

- No instances of the exit gates not being down when an LRT or UPRR train entered the island track circuit, as the result of being held up or pumped for a highway vehicle detect, were observed.

- The exit gates were held up five times for nine seconds or longer as the result of a highway vehicle being detected, each time for an LRT gate down call. These instances were recorded as follows: three times for motorists backing out from under the east entrance gate as it was being lowered; one time for four eastbound motorists backed up in the track area; and one time by shopping cart on the tracks.

- One malfunction of the railroad equipment was observed. During the observation time period, one of the LRT island track circuits failed, causing trains to be detected as motor vehicles and the trapped vehicle detection system to generate an alarm. The track circuit was repaired by LACMTA Signals Maintenance personnel and the system was restored to service as soon as the repairs were completed.

6.12.2 Failure To Detect Highway Vehicles

No instance has been observed on video tape recordings or otherwise reported duing the data collection period where a highway vehicle in the track area has not been detected.

6.12.3 Findings and Conclusions From Followup Operations Review

During the followup operations review time period, the system operated without any observed problems, except for the failure of the island track circuit as noted above. It was observed that the frequency at which the exit gates were held up increased in comparison with the six-month trial installation period, roughly doubling for gate down calls from both LRT and UPRR trains.